

Full Length Research Paper

Mechanical harvest methods efficiency and its impacts on quality of narrow row cotton

Nayra Fernandes Agüero¹, Renildo Luiz Mion^{1*}, Cíntia Michele Baraviera¹, Myllena Teixeira Martins¹, William Lima Crisostomo¹ and Carlos Alberto Viliotti²

¹Universidade Federal de Mato Grosso (UFMT) Campus de Rondonópolis Acadêmicos do Curso de Engenharia Agrícola e Ambiental (ICAT/EAA) Rodovia MT-270, KM 06, 78735-901, Rondonópolis, MT, Brasil.

²Department of Agricultural Engineering, Federal University of Ceará, Fortaleza, Ceará, Brazil.

Received 14 December, 2016; Accepted 16 August, 2017

The large scale cultivation of cotton in the Cerrado areas was made possible by large investments in technology, particularly in mechanized harvesting, which makes the business viable. However, the use of harvesters causes qualitative and quantitative losses to the final product, reducing the profitability of production. This study aimed to evaluate the fiber characteristics of narrow row cotton using harvesting Pro-12 VRS picker and stripper. The experiment was conducted on a farm in the municipalities of Sorriso in the 2014 agricultural season. The experimental design was randomized blocks with seven replicates. The treatments consisted of five harvesting systems: Pro-12 VRS picker, finger stripper with and without field cleaner and brush stripper with and without field cleaner. The efficiency of the harvester was quantified by determining the yield and total loss. Impurities in the harvested cotton were quantified by determining the percentage of bark and stem present in the sample. The following technological fiber characteristics were analyzed through the HVI tool: Trash, UHM, SFC, Elg, Mic, +b, Rd, UI and STR. Cotton in hardened management system has less trash content when harvested with the Pro-12 VRS picker. The Pro-12 VRS picker, however, failed to preserve the intrinsic quality of the fiber.

Key words: Harvester's cotton, platforms picker, fiber cotton characteristics.

INTRODUCTION

Harvesting loss is an important factor for evaluating the performance of a cotton picker. It determines the amount of cotton that is collected from the field, and subsequently cleaned with ginning. Harvesting loss also determines the amount of fiber available for marketing. According to Faulkner et al. (2011), mechanical cotton harvesting increases losses; however, work efficiency gains already far exceed the losses in harvest efficiency.

The cotton stripper has increased harvest efficiency and consequently lower crop losses than harvester spindles (picker) (Faulkner et al., 2011). According to Williford et al. (1994), harvesters will, with time, be able to achieve efficiency of up to 95% but may remain between 85 and 90% efficient.

Boll characteristics and plant height may dramatically affect crop losses. Corley (1966) measured picking

*Corresponding author. E-mail: renildomion@gmail.com.

efficiencies of 95% for fluffy bolls compared to 90 and 65% for weathered and knotty bolls, respectively. The increase in crop losses may be the result of seed cotton, left in the cotton plant or lying on the ground after harvesting (Kepner et al., 1978).

The stripper-harvested cotton contains more foreign matter than cotton harvested with the picker harvester. The greater presence of foreign matter generates higher costs for transport to the cotton bale, as well as the potentially higher cost of processing cotton (Faulkner et al., 2007). However, Faulkner et al. (2011) point out that most stripper harvesters are equipped with seed cotton cleaners, removing about 60% of this material in the field.

Faulkner et al. (2011) demonstrated that the stripper harvester is more efficient than the picker, but the micronaire values, length and uniformity are better with a spindle harvester due to fiber maturity.

According to Mcalister Iii and Rogers (2005), when evaluating the effects of sampling methods on the quality of high-density cotton fiber in the United States, it showed that samples harvested with a picker had better micronaire, fiber strength, average length, length uniformity, yellowness, and decreased neps than samples harvested with a stripper. In another evaluation of sampling methods, Jost and Cothren (2000) studied various row spacings and found no influence of these resistance and fiber fineness. These results highlight the need for a more well-developed understanding of the effects of cotton harvest methods, on the quality of the harvested product.

Therefore, this study aims to present the collection system that provides lower quantitative and qualitative losses of cotton fiber, harvested in the state of Mato Grosso in a dense cultivation system.

MATERIALS AND METHODS

This work was carried out in the municipality of Sorriso, MT (12°35'16" S, 55°48'27" W), average altitude of 360 m, in the 2014 agricultural year. The seeding was performed with cotton variety IMA 5672 with spacing of 0.45 m between rows. At the end of the cycle, fifteen days before harvest, was applied defoliant and maturator throughout the experimental area. Experimental design consisted of a randomized block with the following collection system treatments: Pro-12 VRS picker, finger stripper with field cleaner, finger stripper without field cleaner, brush stripper with field cleaner and brush stripper without field cleaner. Each treatment had seven repetitions, totaling 35 experimental plots.

Each plot measured 3.6 m wide by 30 m long, totaling 108 m². The carriers used to maneuver the machines were 10 m long. The harvesters were conducted by the same operator throughout the experiment, which kept the average speed of the stripper harvester 0.65 m s⁻¹ and Pro-12 VRS picker harvester at an average speed of 1.43 m s⁻¹. The average speed of harvesters was determined by monitoring the time the machines traveled a distance of 50 m. This procedure was performed three times. Thus, speeds were determined by dividing the distance traveled by the average time.

The machines and platforms used in narrow-row cotton harvest were the John Deere model 9930 Pro-12 VRS cotton picker with Agrotech platform for dense cotton with 4 rows spaced 0.45 m apart

(Figure 1A); John Deere brush stripper model 9960 with 6-line platform (Figure 1B); John Deere finger stripper harvester model 9960 with an EMA S-0036 platform 3.66 m wide (Figure 1C).

Before harvesting, the agronomic characteristics were quantified within the borderlines with an area of 4.5 m² measured 5.0 × 0.90 m. Monitoring of the fiber moisture occurred before and during the harvest, using a calibrated Hygron portable measuring device. Fiber samples were removed from within the experimental area and the collection was initiated when the humidity was equal to or less than 7%.

Productivity of experimental areas was estimated using a demarcation 4.5 m², within which whole cotton plants were manually collected. Productivity per hectare was determined by weighing the samples. Pre-harvest losses resulting from climate and crop management conditions were collected manually. This process involved, collecting all seed cotton on the ground surface within the demarcation of 4.5 m². In the laboratory, samples of pre-harvest losses were weighed after removal of foreign material present in the fiber. After the passage of the harvester, post-harvest losses were obtained by manual collection of cotton that remained trapped in the plant, as well as cotton that fell on the soil surface, using the demarcation of 4.5 m² in the center of the plot.

The total sum of the weight of cotton found on the soil surface and remaining in the plant comprises a quantitative total loss of the experiment. As such, it is possible to determine the efficiency of the harvester by Equation 1, as noted by Rodriguez (1977).

$$\text{Efficiency of the harvester} = \frac{100 \times \text{harvested cotton}}{\text{harvested cotton} + \text{post harvest losses}} \quad (1)$$

To determine the qualitative losses, samples were taken from inside the basket of the harvester. These samples were collected at the time that the harvester was in the middle of the plot. In the laboratory, to measure the amount of contaminants present in the fiber in these samples, the impurities were separated from the manual form of fiber and classified into two categories (stem and bark) for later weighing.

The basket of the samples was sent to the laboratory, which passed through a ginner of 20 saws for separating the lump of cotton lint. After ginning, down from the sub-samples was sent to the laboratory of UNICOTOON in Primavera do Leste (MT), and was analyzed using the high volume Instrument (HVI) to determine the following physical characteristics of the fiber: Trash= portion of the sample surface area that is occupied by non-lint material (%); UHM= average fiber length (mm); SFC= short fiber index (%); Elg= elongation (percentage of distension of the fibers, the initial distance to rupture); Mic= micronaire index; +b= degree of yellowing; Rd= degree of reflection (%); Unf= length uniformity (%); STR= rupture strength (gf tex⁻¹).

Data were subjected to analysis of variance by F test, and when significant to Tukey's test, both at 5% probability, with the help of software ASSISTAT 7.7 Beta (Silva, 2016).

RESULTS AND DISCUSSION

No significant difference was observed between the five harvest systems (Table 1). In any harvesting operation, it is common to incur losses, but in the case of cotton harvesting, this occurs because of the lack of efficiency of the harvester, which may fail to harvest cotton still present in the plant. Each harvest system demonstrated efficiency levels well below expectation. This fact is made evident by the high rate of total losses (Table 1), even



Figure 1. (A) John Deere picker harvesting with platform type Pro-12 VRS, (B) Harvester with brush-type picking platform with a view of the coupled field cleaner used in both experiments, (C) Harvester with finger type harvesting platform.

Table 1. Mean efficiency of collection systems (%), total losses (kg ha^{-1} and %) on the basis of cotton harvesting systems.

Harvest system	Efficiency (%)	Total losses (kg ha^{-1})	Total losses (%)
Brush stripper without field cleaner	89.43 ^a	219.97 ^a	11.92 ^a
Brush stripper with field cleaner	88.91 ^a	232.00 ^a	12.57 ^a
Pro-12 VRS picker	88.95 ^a	230.27 ^a	12.48 ^a
Finger stripper without field cleaner	91.10 ^a	182.93 ^a	9.91 ^a
Finger stripper with field cleaner	88.78 ^a	234.77 ^a	12.72 ^a
Average	89.43	206.48	11.19
C.V. (%)	3.11	29.37	29.37

Averages followed by the same letter in the vertical were not statistically different by Tukey's test at 5% probability.

though the productivity of the area was $1845.78 \text{ kg ha}^{-1}$.
In the study carried out by Silva et al. (2007), an

increase in crop losses was attributed to the fact that there are large numbers of bolls closed at harvest,

Table 2. Average bark, stem and total trash in the samples taken from the basket of the harvester (%).

Harvest system	Average (%)		
	Bark	Stem	Total trash
Brush stripper without field cleaner	19.82 ^c	3.16 ^c	22.98 ^c
Brush stripper with field cleaner	5.89 ^b	2.01 ^b	7.95 ^b
Pro-12 VRS picker	0.87 ^a	0.32 ^a	1.19 ^a
Finger stripper without field cleaner	20.98 ^c	3.32 ^c	24.30 ^c
Finger stripper with field cleaner	4.68 ^b	2.36 ^{bc}	7.04 ^b
C.V. (%)	13.33	28.66	28.66

The averages followed by the same letter in the vertical are not statistically different from each other by Tukey's test at 5% probability.

Table 3. Average results of impurities area (Trash), uniformity (Unf), reflectance (Rd), yellowness (+b) and elongation (Elg) cultivar IMA 5672, samples collected in the basket of the harvester.

Harvest system	Area trash (%)	Unf (%)	Rd (%)	+b	Elg (%)
Brush stripper without field cleaner	1.37 ^{ab}	82.9 ^a	75.9 ^a	8.9 ^a	8.1 ^a
Brush stripper with field cleaner	1.23 ^{ab}	83.0 ^a	75.5 ^a	9.0 ^a	7.8 ^a
Pro-12 VRS picker	0.68 ^a	83.1 ^a	75.6 ^a	9.2 ^a	8.1 ^a
Finger stripper without field cleaner	1.54 ^b	83.0 ^a	75.9 ^a	9.0 ^a	8.4 ^a
Finger stripper with field cleaner	0.97 ^{ab}	82.5 ^a	76.8 ^a	9.1 ^a	7.8 ^a
Average	1.4	82.6	75.2	9.1	8.0
C.V. (%)	36.56	1.5	1.62	5.2	4.9

Averages followed by the same letter in the vertical are not statistically different from each other by the Tukey's test at 5% probability.

causing the cotton inlet flow to the machine to be reduced, thereby decreasing the efficiency of the harvester. However, this fact does not corroborate the data from this study because even with the sum of the half-open and closed bolls, there were 95.57% more open bolls. According to Ribeiro et al. (2012) a proportion of 90 to 95% bolls open is adequate for starting the harvest.

To determine the content of impurities present in the cotton sample, taken from the basket of the harvester, the percentage of bark and stem was quantified and according to the data presented in Table 2, the Pro-12 VRS picker platform had the lowest percentage of bark (0.87%) and stem (0.32%). The absence of impurities in the extractor stripper harvester brush and finger provided an increase of 70.3 and 77.7% bark and 36.4 and 28.9% stem, respectively, compared with the brush stripper platform and finger with the presence of the field cleaner. According to Faulkner et al. (2007), the foreign matter can be reduced by using a cleanser, but the levels of these materials are still higher than those found in the cotton harvested with a picker, corroborating data from this study. The Pro-12 VRS picker platform, compared to the brush and finger crop platforms with field cleaner, decreased the presence of stems by 84.08 and 86.21%,

respectively.

In general, the Pro-12 VRS picker harvesting system yielded less waste than the waste stripper harvester. Comparing the stripper harvester, the absence of field cleaner afforded an increase of 65.4 and 71.0% in the presence of garbage in the brush and finger platforms, respectively. In regards to the physical characteristics of the fiber, only the trash was influenced by the harvesting system. As expected, the percentage of total trash was higher in stripper harvesting systems than in picker harvesting systems. The other variables were not affected by the type of harvesting platform used.

There were significant differences between different harvest systems in regards to the percentage of area occupied by impurities, with a level of significance of 5% (Table 3). Cotton harvested with the Pro-12 VRS picker platform had the lowest percentage of impurities within a trash (0.68%), differing significantly only from the comb stripper platform without field cleaner, which, containing 1.54% impurities, had a greater presence of impurities than any other harvest system. However, there was a trend of stripper harvesters without the presence of field cleaner having a higher percentage of impurities.

However, in the cotton samples harvested by a brush stripper platform without field cleaner, a brush stripper

Table 4. Average results of fiber length (UHM), strength (STR), short fiber index (SFI), and micronaire (Mic) for cultivar IMA 5672, for samples collected from the basket of the harvester.

Harvest system	UHM (mm)	STR (gf tex ⁻¹)	SFI	Mic (µg/in)
Brush stripper without field cleaner	27.1 ^a	27.3 ^a	8.9 ^a	3.9 ^a
Brush stripper with field cleaner	27.1 ^a	28.0 ^a	8.6 ^a	3.9 ^a
Pro-12 VRS picker	26.9 ^a	27.8 ^a	8.7 ^a	4.0 ^a
Finger stripper without field cleaner	27.0 ^a	28.0 ^a	7.6 ^a	4.1 ^a
Finger stripper with field cleaner	27.2 ^a	28.9 ^a	8.9 ^a	4.0 ^a
Average	27.3	28.4	8.9	3.9
C.V. (%)	3.10	4.70	14.14	4.90

Averages followed by the same letter in the vertical are not statistically different from each other by the Tukey's test at 5% probability.

with field cleaner, and a finger stripper without field cleaner, the samples were still considered to contain a high percentage of impurities in the samples (> 1.0) (Lamas, 2004). The uniformity of fiber length (Unf) averaged 82.6% that is, falling into the category of high Uniformity Index Fiber Length (Table 3). These values exceed the standard by what the textile industry considers an ideal fiber length uniformity index, ranging between 80 and 82% (Bolsa de Mercadorias and Futuros, 2002).

Reflectance degree (Rd) indicates how much gray or light is the sample. Cotton fiber ranges from 40 to 85 Rd. In this study, the average Rd was 75.9, with one small variation. The degree of yellowness (+b) indicates yellow in the sample. Cotton fiber ranges from 4 +b to 18 +b, and had an average of 9. For the variable elongation (Elg), regardless of study treatment, it was considered very high according to the classification (Table 3).

Industrial demand for fiber length is higher than 28 mm (Freddi et al., 2014), and at an average of 27.4 mm, fiber lengths in this study were lower (Table 4). The characteristic strength (STR) is within the industry compliance standards, since the required standard is more than 28 gf tex⁻¹ and the average STR found in this study was 28.4 gf tex⁻¹, that is their classification fits as medium resistance (Table 4).

The rate of short fibers (SFI) showed an average of 8.5, a low value considering the category. For marketing, values above 10% are considered unfavorable by the market. The fiber micronaire index (Mic), falls within the "fine" category for the brush stripper harvester with and without field cleaner, while the others classify as "average" (Table 4).

Conclusion

Harvesting high density cotton results in a significantly smaller amount of waste when harvested with the Pro-12 VRS picker than with the stripper harvesting system. Field cleaner of the stripper harvester with brush and comb platforms provide cotton with a smaller amount of

stem and bark. The Pro-12 VRS picker harvester failed to preserve the intrinsic quality of the fiber.

CONFLICT OF INTERESTS

The author has not declared any conflict of interests.

ACKNOWLEDGEMENTS

We thank the Instituto Matogrossense de Algodão (IMAMt) financially supporting this research.

REFERENCES

- Bolsa De Mercadorias e Futuros (2002). Resultados de testes no HVI e sua interpretação. São Paulo, Não paginado.
- Corley TE (1966) Basic factors affecting performance of mechanical cotton pickers. Transactions of the American Society of Agricultural Engineers 9(3):326-332.
- Faulkner WB, Wanjura JD, Shaw BW, Hequet E (2007). Effects of harvesting method on foreign matter content, fiber quality, and yarn quality from irrigated cotton on the high plains. ASAE Paper N°. 071113. 2007. International ASABE Annual Conference, Minneapolis, Minnesota: ASABE.
- Faulkner WB, Wanjura JD, Boman RK, Shaw BW, Parnell CB (2011). Evaluation of modern cotton harvest systems on irrigated cotton: Harvester performance. Applied Engineering in Agriculture 27(4):497-506.
- Freddi O Da S, Stoquero A, Peres FSC (2014). Saturação do solo por bases na produtividade e qualidade de fibra do algodoeiro. Nativa 02(01):06-12.
- Jost PH, Cothren TJ (2000). Growth yield of cotton planed in conventional and ultra-narrow row spacing. Crop Science 40:430-435.
- Kepner RA, Bainer R, Barger EL (1978). Principles of Farm Machinery. 3.ed. Westport, Conn: AVI Publishing Company P. 527.
- Lamas FM (2004). Características da Fibra de Algodão Produzida nas Regiões Norte e Nordeste de Mato Grosso do Sul. Dourados: Comunicado Técnico 86:1.
- Mcalister Lii DD, Rogers CD (2005). The effect of harvesting procedures on fiber and yarn quality of ultra-narrow-row cotton. Journal of Cotton Science 9(1):15-23.
- Ribeiro ES, Cruz EF, Belot JL (2012). Uso adequado das colheitadeiras. In: BELOT, J. L. Manual de boas práticas de manejo do algodoeiro em Mato Grosso. Cuiabá: IMAMt: AMPA pp. 180-191.

Rodriguez HE (1977). Characteristics of cotton strains related to mechanical picker efficiency. Thesis of Master of Science. Mississippi State University. Mississippi P 26.

Silva FAS, Azevedo CAV (2016). O Software Assistat Versão 7.7 e seu uso na análise de dados experimentais. African Journal of Agricultural Research 11(39):3733-3740.

Silva RP, Souza FG, Cortez JW, Furlani CEA, Vigna GP (2007). Variabilidade espacial E controle estatístico do processo de perdas na colheita mecanizada do algodoeiro. Engenharia Agrícola 27(3):742-752.

Williford JR, Brashears AD, Barker GL (1994). Harvesting. In: Cotton Ginners Handbook, Washington, D.C.: USDA Agricultural Research Service pp. 11-16.