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Cotton and fiber quality in function of picker harvest speed

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A B S T R A C T

Cotton price is determined by the quality of the fiber, which can be damaged at the time of harvest, in addition to quantitative losses of non-harvested plume. Therefore, this study aimed to analyse soil and plant losses, and the quality of cotton fiber in relation to five harvest speeds (5, 6, 7, 8, and 9 km h^{-1}) in the spindle system (picker). The experiment was conducted in Lucas do Rio Verde, Mato Grosso, Brazil. A randomized complete block design was used on plots of 0.9 ha, with 20 plot, five speeds, and four blocks. The results showed that the studied speeds did not significantly influence losses on the soil and plant, or the quality of the cotton fiber; therefore, the highest speed may be recommended.

Palavras-chave:
picker
sistema de fusos
características de fibra
Gossypium hirsutum

Algodão e qualidade da fibra em função da velocidade de colheita picker

R E S U M O

O preço do algodão é determinado pela qualidade da fibra, que pode ser danificada no momento da colheita, além de perdas quantitativas de pluma não colhidas. Neste contexto, o estudo teve como objetivo analisar as perdas no solo e na planta e a qualidade da fibra de algodão em relação a cinco velocidades de colheita (5, 6, 7, 8 e 9 km h^{-1}) no sistema de fusos. O experimento foi realizado em Lucas do Rio Verde, Mato Grosso, Brasil. Um delineamento de blocos completamente casualizados (DBC) foi usado em talhão de 0,9 ha, 20 parcelas, 5 velocidades e 4 repetições. Concluiu-se que as velocidades estudadas não influenciaram significativamente as perdas no solo e na planta e a qualidade da fibra de algodão, recomendando-se usar a velocidade mais alta.

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Introduction

Data from the Brazilian Food Supply Corporation of the Brazilian Ministry of Agriculture (CONAB/MAPA) indicate that the average production of lint cotton was 1.28 million tons in the 2015/2016 harvest in Brazil. The average selling price in December 2016 was approximately US$23.75 per arroba (CONAB, 2017), and the dollar exchange rate was R$3,163.00, per arroba (33.07 lb or 14.69 kg). Therefore, according to the criterion established by Vieira et al. (2001), which considers acceptable harvest losses of approximately 10%, it is estimated that, on average, cotton harvest losses in 2016/2017 in Brazil would represent US$202 million.

When analyzing the operational costs of cotton production, the harvest is the most representative mechanical operation. A study in Mato Grosso evaluating two speeds of picker harvester displacement, 3.6 and 7.2 km h^{-1}, observed that the soil loss increased by 100 kg ha^{-1} with the speed of 7.2 km h^{-1}, while total losses increased by 125 kg ha^{-1} (Ferreira et al., 2014).

Analyzing the ideal speed contrast for the harvesting system is a challenge. Proposals for mechanization with higher speeds are needed for greater field capacity, while lower speeds may lead to lower quantitative losses in the harvest. Therefore, if an optimum speed is sought, the highest operating efficiency with minimum losses should be aimed for.

As the speed of the spindles is proportional to the speed of displacement, it can be hypothesized that higher displacement speeds can affect the quantitative and qualitative losses of cotton fiber. Additionally, all systems of the machine may be involved, such as the shredders or air capacity, in the removal and transportation of cotton, and may be unsuitable for higher displacement speeds.

Thus, assuming that the speed of mechanized upland cotton harvesting interferes with quantitative and qualitative fiber loss, the objective of this study was to evaluate these losses by analyzing five different displacement speeds (5, 6, 7, 8, and 9 km h^{-1}) from a harvester with a picker system.

Material and Methods

The experiment was carried out in the agricultural year 2015, in the municipality of Lucas do Rio Verde, Mato Grosso, Brazil. The experimental area is located at 13° 00' 35" S, 56° 05' 13" W and has an average altitude of 413 m. During the experiment, the crop was monitored by property technicians to control pests and diseases, and to carry out all the operations necessary for proper establishment of the crop.

According to the Köppen classification, the climate of the region is tropical with dry winters and rainy summers. The soil of the experimental area was classified as a dystrophic Red Yellow Latossolo, presenting a clayey textural class (EMBRAPA, 2013). Rainfall was collected during the crop cycle by a rain gauge on the farm, and a value of 1,584 mm was recorded.

Seeding was carried out on January 31 in a conventional planting system, with row spacings of 0.76 m, for a total of 130,000 plants ha^{-1}. The cultivar TMG 81 WS was used, which is characterized by a late cycle of 180 days and nematode tolerance.

In the experiment, a John Deere model 7760 harvester with a picker system, six lines, 4.5 m wide and 395 kW (537 hp) was used for cotton harvesting. Harvesting was carried out at five medium speeds (5, 6, 7, 8, and 9 km h^{-1}) to verify the relationship of speed with crop losses and cotton fiber quality. Notably, 9 km h^{-1} was performed in the first gear of the harvester, as the highest gear for harvesting is 8 km h^{-1}.

A randomized block design was used in a plot of 0.9 ha (useful plot), with 20 plots (100 × 4.5 m), 50 m distant in the same line, and corridors of the same size between blocks.

To evaluate losses, the remaining bolls in the soil represented losses in the soil, and the remaining bolls of the plant represented losses in the plant; these were collected manually after the machine was transferred to the plot, and subdivided into losses in the lower, middle, and upper thirds. Then, the values for each plot from each treatment were summed to obtain the total losses. Subsequently, all values were corrected, and the results were extrapolated from those obtained in 4.5 m^2 (plot) to one hectare. The percentage loss was also determined and related to the estimated values for crop yield.

The yield was determined in the useful area of the frame (4.5 × 1.0 m), using the breadth of the harvester platform as a base. All bolls present in the plant in each plot were collected manually before the mechanized harvest, without losses in the harvest, thus representing gross productivity.

Cotton samples obtained from different treatments were subjected to roller machines by IAC Campinas. Subsequently the samples were sent to the Minas Cotton Laboratory in Uberlândia, Minas Gerais State, Brazil, to analyze their characteristics using a high volume instrument (HVI) system: spinning consistency index, cotton wool moisture in the HVI machine comb, micronaire index, cotton fiber maturity, fiber content, degree of reflectance, yellowing index, impurity content, index of uniformity of length, and percentage of the area occupied by the sum of impure particles.

The field capacity was determined by Eq. 1:

$$C_a = w\ V\ 0.1 \tag{1}$$

in which:

C_a - field capacity, area basis, ha h^{-1};
w - machine working width, m; and
V - travel speed, km h^{-1}.

The results were analyzed for normality and homoscedasticity using the Shapiro-Wilk and Bartlett tests; as the results were significant, the results of losses and fiber characteristics were submitted to analysis of variance, using an F test of 5% probability with the statistical software R Core Team (2017). When necessary, data were transformed by y = log (x).

Results and Discussion

The average yield was 3,793 kg ha^{-1}, which was similar to that found in the study of Belot & Vilela (2006), who obtained an average yield of 3,826 kg ha^{-1}; and Kazama et al. (2015), who observed 3,911.2 kg ha^{-1} for cultivar FMT 701 and 4,108.8 kg ha^{-1} for cultivar IMACD 408.

Harvest speed had no significant effect on cotton losses in the soil, plants, and total losses (Table 1). Means with original values, transformed only for statistical analysis.

Although it was expected that the higher harvest speed could collect more impurities due to the higher speed of the spindles, the results demonstrate that the harvester has an efficient system to remove the lint with minimum impurities when the adjustments and maintenances are carefully administered, at higher speeds.

Larger losses were observed in the lower-third compared with the medium- and higher-thirds (Table 1), with values of 0.55, 015, and 0.25 respectively. To explain the losses along the stem, determination of cotton plant maturation is important, as its type of growth is characterized as indeterminate. Flowers, fruits, floral buds, and buds can be found in the same cotton plant. Indeterminate growth causes a lack of uniformity in the formation, maturation, and dehiscence of the caps from the base to the apex. There may be a difference of up to 60 days between the first and last dehiscence (Carvalho, 1973). Thus, as the lower third of the plant's crown completes maturation first, the fiber of these canopies become more vulnerable to environmental conditions, causing them go against the plant architecture, facing downwards, and damaging the harvest of the plant (Figure 1).

Table 1. Mean results of lower (LL), mean (ML), higher (HL), plant (PL), soil (SL), and total (TL) losses under different harvester speed

Speed km h^{-1}	LL	ML	HL*	PL	SL*	TL*
	%					
5	0.46	0.17	0.24	0.87	2.71	3.58
6	0.74	0.15	0.10	0.98	3.13	4.11
7	0.41	0.13	0.58	1.11	5.03	6.14
8	0.39	0.17	0.21	0.77	4.70	5.47
9	0.76	0.14	0.12	1.01	5.52	6.54
Mean	0.55	0.15	0.25	0.95	4.22	5.16
p	0.13	0.97	0.60	0.84	0.17	0.37
CV (%)	44.40	77.72	178.74	47.20	32.87	24.76

* Transformed values log (x); CV: Coefficient of variation; $p < 0.05$

Figure 1. Experimental plot of cotton at harvest. In particular, the plume of the lower third

Cotton produces larger fruits in the first and lower thirds because these parts receive more assimilates from the vegetative leaves, present in the main stem, especially in the lower nodes, because they have larger (almost double the size) and younger stems (Wullschleger & Oosterhuis, 1990). This demonstrates that there are greater losses in cotton harvest where the plant is more productive; thus, it is necessary to develop harvesting platforms that are more efficient in the plant soil than in the upper-third. Similarly, picking cotton closer to the main stem, where the larger buds are in the top positions, could maximize harvesting efficiency.

Soares et al. (1999) noted that 80% of production is confined to the bottom- and middle-third of the cotton, in the first and second fruit position, in relation to the distance from the main stem.

This difference in maturation directly influences the removal of the cylindrical spindles, as greener plants are more difficult to release. This may also explain why the mean losses in the upper-third are greater than the average losses in the middle-third, as maturity occurs last in the parts at the top of the plant; these may not be harvested because the boll did not completely open.

Another explanation for the greater losses in the lower third of the plant is that the spindles of the lower part of the platform are subjected to greater wear due to the friction and abrasions of soil particles (Silva et al., 2015). These spindles must be replaced as they have more rounded edges, fewer sharp edges, and shallower grooves, and less efficiently collect the bushings.

Average soil losses of 4.22% were observed in relation to crop yield. Soil losses are explained by the displacement and friction of the harvester with the cotton plants, which are detached from the stem and deposited in the soil when they hit with the machine. The higher losses in the soil compared with the plant, are due to the detachment of the mass of the whole bundle at the moment of friction between the machine with the plant.

Genetic improvement to strengthen the receptacle and the floral peduncle (structure responsible for connecting the floral bud to the vegetative branch) may reduce soil losses, to reduce the sensitivity of the bud so that it does not detach due to friction with the machine.

The lower soil, plant, and total losses (4.22, 0.95, and 5.16, respectively) reflect the experience of the harvester operator, who makes adjustments to the machines with criterion, as the adjustment of the pressure plates allows the spindles to harvest the corns closer to the vegetative branch. Fairer adjustments would allow greater extraction of the feather, but with greater accumulation of impurities in the bales due to the bracts and sepals being harvested next to the cotton, which could impair fiber quality.

Silva et al. (2007) evaluated cotton harvest losses in Ipameri, GO, and observed average soil losses of 334.5 kg ha^{-1}, and 11.4% for yields (2,925 kg ha^{-1}). Ferreira et al. (2015) concluded that there was a significant interaction between cultivar and harvesting speed in the spindle system for soil losses. In that study, speeds of 3.6 and 7.2 km h^{-1} were analyzed and the highest soil losses were observed at the highest speed. This differs from the results of the present study, in which no differences were observed (9 km h^{-1}, first gear); there was no increase in losses, which demonstrates the ability of the harvester to collect the plume.

The results for TL were lower than those reported by Silva et al. (2007), who observed a TL of 16.7% in a picker harvesting system. This was also below the values reported in the literature for the Cerrado, with total losses between 12.5% (Freire et al., 1995) and 10% (Vieira et al., 2001).

There was no significant difference in cotton fiber quality in any of the analyzed variables with the five different work speeds of the harvester: spinning consistency index, cotton moisture, micronaire index, cotton fiber maturity, mean upper half length, fiber content or index, resistance, elongation at fiber breakage, degree of reflectance, yellowing index, impurities content, length uniformity index, and the percentage of the area occupied by the sum of the impure particles (Tables 2 and 3).

Previous studies have reported that picker and stripper systems can discriminate fiber quality; multivariate analysis demonstrated that the higher levels of impurities collected by the stripper system damaged fiber quality, as the maturity, resistance, yellowing, short fibers and reflectance, the length of the fiber being the only variable that was not influenced by the harvest system (Kazama et al., 2015).

Some factors should be considered when discussing the quality of cotton fiber, such as humidity; this is the percentage of water present in the sample, and varies with the time, temperature, and humidity to which the samples are exposed. Constant environmental humidity is required to maintain the acuity and accuracy of HVI test results. The average level of moisture found in the sample at the time of analysis was 8.41%, which was considered high (8.1 to 9.9%). Optimal acuity and precision have been obtained with mean humidity of 6.5 to 8.0% (Sestren & Lima, 2007).

According to the American Society for Testing and Materials (ASTM D) 1448-79, the results obtained for the micronaire index with all treatments were regular or medium (4.0 to 4.9), at 4.6. This classification was also obtained by Sluijs et al. (2015), with mean value of 4.16.

Sui et al. (2010) concluded that the micronaire value is lower following mechanized harvest than with manual harvest, as the machine also harvests the immature lint and impurities (mainly leaves and stem parts).

The micronaire index is important for the commercialization of fiber quality, as high values (> 5.0) are classified as very thick fibers due to the increased percentage of irregularity and imperfections in the cross section of the yarn. However, low values (< 3.5) suggest that the fiber is immature and can cause tissue defects (neps), and, consequently, low incorporation of dye during finishing (Kljun et al., 2014).

According to ASTM D 1447, the length uniformity index was considered regular (80 to 82%), with average value of 80.23%.

When the breakage strength of fibers was analyzed according to ASTM D 1445, the mean value between the speeds was 29.12 and was thus classified as high (27.0-29.0). This classification was different from that obtained by Sluijs et al. (2015), with a mean value of 30.25, falling into the "very high" classification for values exceeding 30.00.

Studies have shown that fiber strength is more responsive to the environment than length and thickness. Other studies have indicated that resistance is linked to genetic factors (Smith & Coyle, 1997); Coyle & Smith (1997) studied six genotypes and showed that fiber resistance is inversely correlated with yield, suggesting that stronger fibers require plant energy that could be directed towards productivity, and thus the mass and number of fibers. The authors stated that this relationship must be broken through genetic improvement or at the molecular level.

The fiber begins to thicken 15-20 days after anthesis; for example, cellulose rings are deposited during the formation

Table 2. Mean values for spinning consistency index (SCI), cotton moisture (Mst), micronaire index (Mic), maturity of cotton fiber (Mat), mean upper-half length (UHML), and uniformity index length (UNF), under different harvester speed

Speed km h^{-1}	SCI (index)	Mst %	Mic μg in^{-1}	Mat %	UHML mm	UNF %
5	119.50	8.30	4.62	87	26.64	80.80
6	116.50	8.60	4.60	87	26.39	80.40
7	107.50	8.50	4.47	87	26.24	79.23
8	109.80	8.40	4.61	87	26.16	79.70
9	114.30	8.30	4.68	87	26.18	81.03
Mean	113.50	8.41	4.60	87	26.32	80.23
p	0.42	0.08	0.40	0.87	0.82	0.42
CV (%)	8.41	1.61	4.51	1.04	2.44	1.84

CV: Coefficient of variation; $p < 0.05$

Table 3. Mean values for short fiber index (SFI), strength (STR), elongation at fiber fracture (Elg), degree of reflectance (Rd), yellowing index (+b), impurity content (TrCnt), percentage of the area occupied by the sum of impure particles (TrAr), under different harvester speed

Speed km h^{-1}	SFI %	STR g tex^{-1}	Elg %	Rd %	+b	TrCnt	TrAr %
5	11.25	30.08	5.93	81.03	8.25	4.50	0.04
6	12.00	29.88	6.03	80.20	8.63	5.00	0.06
7	12.65	28.40	6.00	80.23	8.23	4.25	0.07
8	12.98	28.80	6.03	80.65	8.53	8.75	0.10
9	12.33	28.43	6.08	80.18	8.35	5.75	0.09
Mean	12.24	29.12	6.01	80.46	8.40	5.65	0.07
p	0.66	0.05	0.98	0.66	0.47	0.38	0.17
CV (%)	13.75	3.09	5.58	1.19	4.27	60.26	48

CV: Coefficient of variation; $p < 0.05$

of the secondary wall until about 50 days after the anthesis. Cellulose is deposited at slightly different angles during this process, which provides fiber resistance (Davidonis et al., 2004).

Analysis of the mean maturity index (as a percentage) revealed a value of 87%. According to Fonseca & Santana (2002), this is considered mature (80% or more), and is adequate according to previous literature.

The primary cell wall and cuticle make up approximately 2% of the total wall thickness (Ramey, 1982; Ryser, 1985). The remainder of the fiber wall is composed of 98% cellulose in the secondary wall, which thickens significantly as polymerized photosynthates are deposited during fiber maturation. The mean length (UHML) in the present study was 26.32 mm, which was considered regular (25.16 to 27.94 mm) according to ASTM D-1447. Longer fibers are preferred, because they are stronger and thinner with spinning; therefore, analysis of the average length of the upper-half of the fiber is important for the commercialization of the lot. In contrast to the present study, Sluijs et al. (2015) obtained a mean value of 30.6 mm, which refers to the "long" classification.

The length and diameter are largely dependent on genetics. However, the maturation properties that are dependent on photosynthetic deposition on the cell wall of the fiber are more sensitive to changes in the environment (Bradow & Davidonis, 2000).

On average fiber elongation value of 6.01% was observed, which is considered regular according to ASTM D 1445. Elongation allows the elastic behavior of the textile material submitted to a tensile stress to be evaluated, providing information on the expected reliability (Fonseca & Santana, 2003).

Regarding the short fiber index, a mean value of 12.24% was obtained, which, according to ASTM D-1444, is considered medium (10 to 13%). Short fibers are not desired in textile processes as they cause waste and reduce production efficiency; factors affecting the short fiber index can be genetic, environmental, and associated with ginning, and the early application of defoliant (Oz, 2014).

Other important fiber characteristics, with reference to the color and fluorescence of the material, are the reflectance and yellowing variables, which in the present study presented mean values of 80.45% and 8.39, respectively.

The values for reflectance and yellowing (80.46% and 8.40, respectively) were preferable when compared with those obtained by Ge et al. (2008), at 78.2% and 9.84, respectively.

The level of impurities corresponds to the incidence of non-fibrous matter contained in the cotton sample when compared to the universal physical standards (Fonseca & Santana, 2002). Table 3 shows that the different speeds did not lead to different levels of impurities, with an average value of 5.65, which is within the range considered acceptable for commercialization by Costa et al. (2006).

Studies have shown that fiber quality may change with the application of biostimulants to the seed, which can lead to fiber quality that is worse than that of the control, as cotton has high plasticity and hormonal complexity (Silva et al., 2016).

In contrast to Table 1, the coefficients of variation were low (Tables 2 and 3), because the characteristics and quality of the fiber are not as variable as the quantitative losses. Although the variables are provided by the HVI method, which is the method used most often for commercial purposes, more details relating to the qualitative parameters may be observed by the AFIS analysis, providing opportunities for further study.

The spacing used during sowing in this experiment was 0.76 m, and the platform of the harvester had six lines. Thus, the platform totals 4.5 m and directly influences the harvesting capacity of the crop. Effective field capacity is the performance ratio obtained if the machine operates at full speed at rated speed using 100% of its width.

Five speeds, i.e., five different effective field capacities were evaluated; at 5 km h^{-1} this value was 2.3 ha h^{-1}; with increasing speed, field capacity increased, and values of 2.7; 3.2; 3.6, and 4.1 ha h^{-1}, respectively, were observed at 6, 7, 8, and km h^{-1}. Thus, these values excluded time lost, which includes time taken for maintenance, supply, and maneuvers.

Because of the non-significant results obtained with the studied harvest speeds, it can be stated that between the displacements of 5 and 9 km h^{-1}, the highest speed of the harvesters should be used, as the speed did not influence the quantitative and qualitative losses of the fiber.

Conclusion

Soil and plant losses and qualitative losses were not affected by increased harvesting speed.

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