EVALUATION OF SOME PERFORMANCE PARAMETERS OF THREE COMBINE HARVESTERS OF SUGARCANE (SACCHARUM OFFICINARUM)

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ABSTRACT

To evaluate the raw-material quality supplied for combine harvesters, SANTAL-115 (M1), TOFT R-300 (M2), and MF-201 (M3), were subjected to six Test Trials (TT). The variety was Co331, an erect cane, planted in a row spacing of 1.40 m, with a stalk density in the cane row ranging from 4.47 to 16.85 kg/m. The soil was Latosol Red Yellow, sandy phase, and textural natural sandy grouping with a field gradient of less than 2% and moisture soil conditions ranging from 5.09 to 9.85% at the time of trial. From the data obtained from TT, the following was determined: Total Extraneous Material Index (TEI%); Top Index (TI%); Leaf and Dry Leaf Index (LI%); Root Index (RI%); Soil Index (SI%); and Non-Selected Material Index (NI%), parameters of Efficacy of Manipulation (EM%), Effective Capacity (EC), “Practical” Effective Capacity (EC’), Frequency of Length of Chopped Canes (F%), were evaluated. Statistical analysis of the values found included the comparisons among means by the method of Tukey. Each index was analyzed separately by verifying harvester effects in Test Trials and harvester x TT interaction.

The mean indices obtained (Tukey 5%) by harvesters were as follows:

- M1 (TEI% = 9.64; TI% = 4.61; LI% = 1.43; RI% = 0.68; SI% = 1.28 and NI% = 0.92);
- M2 (TEI% = 7.71; TI% = 4.61; LI% = 1.26; RI% = 0.41; SI% = 0.61 and NI% = 0.82); and
- M3 (TEI% = 9.93; TI% = 6.74; LI% = 1.78; RI% = 0.32; SI% = 0.59 and NI% = 0.49).

Efficacy of Manipulation was non-significant among harvesters,
ranging from 74.9 - 92.0 (SANTAL-115); 72.0 - 94.5 (TOFT R-300), and 75.0 - 93.5 (MF-201) in all Test Trials (TT). All EC were affected by field conditions. In the TT R3, EC was lower than the rest. SANTAL-115 presented the lowest EC differing from others. On the other hand, the rests were non-significant between them. All EC' had similar behavior as EC. TOFT R-300 presented the best performance. The others presented similar performances.

INTRODUCTION

In Brazil, until the end of the harvest 77/78, a total of 338 combine harvesters were already performing. According to PLANALSUCAR estimates, an area of 125,104 ha were harvested during this time by those combine harvesters. The most predominant models on the Brazilian market are: SANTAL-115; MF-201 and TOFT R-300. On the other hand, the majority of the field trials carried out for the present has not followed a uniform methodology and not always a more efficient control on the various factors involved in the performance has been observed. This has caused difficulty to define parameters for evaluation of combine harvester performance in Brazil, aiming at studies for comparative performances.

The present study aimed to define and evaluate parameters of operational performance related to the raw-material quality harvested by the most used combines in this country, under similar operational field conditions.

EXPERIMENTAL PROCEDURE

The combine harvesters tested were: SANTAL-115; TOFT R-300 and MASSEY FERGUSON-201, coded M1, M2 and M3, respectively. The variety was Co331, an erect cane, according to the criterium proposed by Ripoli et al2; the burn occurred between 12 and 14 hours before the trials, considered "bad", according to the criterium proposed by Balastreire and Ripoli1; inter-row spacing was 1.40 m and furrow length ranged from 220 to 250 m; field gradient was less than 2%; and the soil was Latosol sandy phase, a textural natural sandy grouping.

Cane rows were levelled, resulting to absence of furrows. Table 1 shows other culture conditions for each Test Trial, coded by TT. Rear dumping trucks to collect samples, chronometer, weighing balance, plastic bags, stakes, tape measures, a 6 mm mesh sieving, tarpaulin, wood triangle and knives, were also utilized. Each combine harvester was conducted by a single experienced operator in all TT.

Culture Conditions

For culture conditions in all six TT, a criterium proposed by Ripoli et al3 was used, considering the following aspects; means stalk length, mean stalk density/linear meter (in kg/linear meter and in number of stalks/linear meter); stand cane field; burn quality; moisture soil conditions (in the first superficially 10 cm); soil
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granulometer and age level of culture ripening.

a. Mean Stalk Length

Sixty stalks were taken at random in the area of each TT, being twenty in the rows where each combine harvester has performed. Height of the bottom of the first internode was measured (to soil level) to the first visible dewlap in the leaf of each stalk, by determining the arithmetic mean of the obtained length.

![Diagram of stalk types](image)

**FIGURE 1.** Standard triangle for quantitative evaluation of the sugarcane stand

b. Mean Stalk Density/Linear Meter

Twenty randomized samples in each TT were taken (a total of 120 samples). Each sample is formed by counting existing stalks in 10 linear meters. Only milling stalks were considered, therefore, “sucking shoots”, deteriorized stalks, etc., were not computed. The arithmetic mean of samples were then determined.

For a careful evaluation of stalk density in terms of kg/linear meter, the following was determined: weight of chopped stalks harvested by the combine which was then added up to the proportional weight obtained by the stalk non-harvested, and the total was divided into the corresponding furrow length.

c. Stand Cane Field

Stand cane field refers to erect, lodged and recumbent stalks in the rows and the respective stalk density in each situation. The standard rectangular triangle was employed for this quantity, proposed by Ripoli et al3, whose criterium of specification for the erect, lodged and recumbent stands are shown in Fig. 1.

Twenty samples were taken at random from one meter of furrow length by TT (a total of 120 samples), by employing the standard triangle at the bottom of each existing stalk within this space. The number of the erect, lodged and recumbent canes was recorded and each condition determined by percentage.
d. Burn Condition

The criterion of qualifying burn was adopted with only two options: good or bad, according to Balastreire and Ripoli. Burn is considered good when only stalks and the top remain, and is bad when leaves, dry leaves, culture remnants and weeds remain, aside from stalks and the top.

e. Moisture Soil Conditions

Fifteen soil samples were taken for each TT (5 samples per harvester tested), at 0-10 cm in depth, according to the methodology proposed by Ripoli et al. The samples were taken at random soon after the harvester performance in the cane row. Moisture content (dry basis) was determined by drying up in an oven at 105-110°C, for 48 hours.

f. Soil Granulometry

The same samples referred to the previous item were also used for soil granulometric analysis. Each 15 samples corresponding to the same TT was mixed and homogenized, taking from there a compound sample. The clay fraction was determined by the pipette method adopted by Steel and Bradfield, and the sandy fraction was separated by the humid sieving (sieve 270 – diameter 0.053 mm) and then fractioned by a dry sieving. After that, a textural soil group was determined, according to the diagram proposed by USDA Soil Survey.

g. Age and Degree of Culture Ripening

The sugarcane field age was obtained by means of information of the agricultural section of the sugarmill where trials were carried out. Ripening degree was obtained by means of a cane field refractometer in 10 readings per TT, by taking the average of 10 randomized readings.

Combine Harvester Test

Evaluation of the operational performance of harvesters in each TT covered the following determination, according to Mialhe and Ripoli.

a. Total Extraneous Material Index (TEI%)

The total extraneous material index (TEI%) is an indicator of percentage of extraneous material in weight, contained in the product at the end of harvest (on infield transport). “Tops”, leaves and dry leaves, soil, roots and non-selected material are considered extraneous materials.

The total extraneous material index is expressed by the equation:

\[ \text{TEI} \% = \frac{\text{TE}}{S} \times 100 \]
where:

\[ \text{TE} = \text{total quantity in weight, of extraneous material contained in sample } S \text{ (kg).} \]

\[ S = \text{samples harvested by the combine and loaded in the truck (kg).} \]

**b. Top Index (TI %)**

It is expressed by the equation:

\[ \text{TI} \% = \frac{T + t}{S} - 100 \]

where:

\[ t = \text{quantity, in weight, of tops aggregate to all chopped canes contained in samples } S \text{ (kg).} \]

\[ T = \text{quantity, in weight, of free tops contained in samples } S \text{ (kg).} \]

**c. Leaf and Dry Leaf Index (LI %)**

It is expressed by the equation:

\[ \text{EI} \% = \frac{\text{DL}}{S} - 100 \]

where:

\[ \text{DL} = \text{quantity, in weight, of leaves and dry leaves contained in sample } S \text{ (kg).} \]

**d. Root Index (RI %)**

It is expressed by the equation:

\[ \text{RI} \% = \frac{\text{RO}}{S} - 100 \]

where:

\[ \text{RO} = \text{quantity, in weight, of roots contained in sample } S \text{ (kg).} \]

**e. Soil Index (SI %)**

It is expressed by the equation:

\[ \text{SI} \% = \frac{\text{SO}}{S} - 100 \]

where:

\[ \text{SO} = \text{quantity, in weight, of roots contained in sample } S \text{ (kg).} \]
where:

\[ \text{TE} = \text{total quantity in weight, of extraneous material contained in sample } S \text{ (kg).} \]

\[ S = \text{samples harvested by the combine and loaded in the truck (kg).} \]

b. Top Index (TI %)

It is expressed by the equation:

\[ \text{TI} \% = \frac{T + t}{S} - 100 \]

where:

\[ t = \text{quantity, in weight, of tops aggregate to all chopped canes contained in samples } S \text{ (kg).} \]

\[ T = \text{quantity, in weight, of free tops contained in samples } S \text{ (kg).} \]

c. Leaf and Dry Leaf Index (LI %)

It is expressed by the equation:

\[ \text{EI} \% = \frac{D L}{S} - 100 \]

where:

\[ D L = \text{quantity, in weight, of leaves and dry leaves contained in sample } S \text{ (kg).} \]

d. Root Index (RI %)

It is expressed by the equation:

\[ \text{RI} \% = \frac{R O}{S} - 100 \]

where:

\[ R O = \text{quantity, in weight, of roots contained in sample } S \text{ (kg).} \]

e. Soil Index (SI %)

It is expressed by the equation:

\[ \text{SI} \% = \frac{S O}{S} - 100 \]

where:

\[ S O = \text{quantity, in weight, of roots contained in sample } S \text{ (kg).} \]
FIGURE 2. Flow chart of separation of the extraneous material contained in sample S.
f. Non-Selected Material Index (NI%) 

This index result from the general process for separation due to the size of its components. It is expressed by the equation:

\[ \text{NI}\% = \frac{\text{NO}}{\text{S}} - 100 \]

where:

\( \text{NO} \) = quantity, in weight, of remaining material from separation and non-selected (kg.).

g. Scheme of Sample Separation

To obtain indexes described from a to f, weighing determination of different sample S components is demanded. For that, a scheme of separation, which is illustrated in the flow chart in Fig. 2, is established.

h. Efficacy of Manipulation (EM%)

Efficacy of Manipulation (EM%) is defined, according to Mialhe and Ripoli\(^2\), as a ratio between the chopped cane (CC) at the end of harvest (on infield transport) and the estimated stalk density (SD) presented in the cane row, in its natural state, or:

\[ \text{EM}\% = \frac{\text{CC}}{\text{SD}} - 100 \]

Chopped cane at the end of harvest (CC) was obtained by means of separation and weighing sample S, or:

\[ \text{CC} = \text{S} - \text{TE} \]

where:

\( \text{TE} \) is the quantity of extraneous material contained in sample S.

The estimated quantity of stalk density (SD) contained in the cane row in its natural state, is determined by considering the following aspects: quantity of cane “in natura” \( (\text{C}_{\text{in}}) \) in the field, is equivalent to a determined quantity of chopped canes (CC) associated with the extraneous material (TE), or:

\[ \text{C}_{\text{in}} = \text{SD} + \text{TE} \]

After the cane is harvested by the combine, part of SD is effectively harvested and transformed into CC, and the other is lost in the sugarcane field, being the amount of losses (L):

\[ \text{SD} = \text{CC} + \text{L} \]

Thus, the denominator of the equation (I), is obtained by summing the quantity of chopped canes (CC) in the sample S, free of extraneous material (TE), with the quantity of chopped canes lost in the sugarcane field for each of the cane row in the trials, equivalent to a replication.
In the trials, the data for evaluation of EM% was obtained by using the following sequences:

1) in a cane row, of a previously known length, a certain harvester and the infield transport were employed; the harvester moved at the maximum speed permitted by the cane row conditions;

2) after harvesting the cane row, the following was determined: — in the sugarcane field: sampling for determination of losses of cane in the field; in the sugarmill yard: determination of the net load (sample), separation of the extraneous material and determination of the weight of chopped canes (CC);

3) Sampling of losses in the sugarcane field was performed as follows: 5 randomized samples were taken, of 10 m in length/1.4 m in width over the cane row harvested, obtaining therefore, an area of 14 m²/sample.

In each Test Trial (coded by TT), 4 cane rows were harvested per tested combine, totalling 20 samples of losses per harvest and per TT.

Within the corresponding area for each sample, all stalks were collected, or the chopped canes that were not harvested by the combine. Furthermore, in the ratooning, by means of knives, the remnants of the remaining stalks were cut. All of these materials were bagged and weighed, and their value in the field card was recorded.

For each group of 5 samples corresponding to a single cane row, the total weight of the harvested material was then summed. This value corresponds to losses at 70 m² of the sampled area. By associating this data with the cane row harvested, an estimated of losses (L) in the sugarcane field was obtained.

1. Effective Capacities – EC and EC'

Two methods for evaluation of this parameter were adopted, according to Mialhe and Ripoli, who expressed the Effective Capacity (EC) as product of effective speed of movement of the harvester in the cane row (Es), stalk density at the same (SD) and the Efficacy of Manipulation (EM%), or:

\[ EC = Es \times SD \times EM \]

where:

- \( EC \) = Effective Capacity (kg/s)
- \( Es \) = Effective speed (m/s)
- \( SD \) = Stalk density in the cane row (kg/m)
- \( EM \) = Efficacy of Manipulation (%)

The second method is the commonly adopted in practice and defines the "Practical" Effective Capacity (EC') as a ratio between quantity of material har-
vested by the combine (CC + E) over the corresponding time harvest taken, or:

\[ EC' = \frac{CC + TE}{Th} = \frac{S}{Th} \]

where:

- \( EC' \) = “Practical” Effective Capacity (kg/s)
- \( DD \) = Total of chopped cane harvested (kg)
- \( TE \) = Total of extraneous material together with CC (kg)
- \( S = CC + TE \) = Total sample harvested (kg)
- \( Th \) = Harvest time in the cane row

\( j. \) Frequency of Length of Chopped Canes (F\%)

To evaluate the variation in the length of chopped canes, randomized samples of 200 units each, were taken and the length of each chopped cane measured with the precision of 0.5 cm. Thus, 30 samples were taken in the last five TT, totalling 6,000 (six thousand) chopped canes. For replications of each harvester, the respective polygons of frequency were constructed by considering intervals of frequency of 5 cm.

For each harvester in each TT, two randomized replications were taken. Each replication consisted of the total weight of the material harvested by the combine (chopped cane – CC + TE).

When the cane row which corresponds to a single replication was harvested, the infield transport took all samples to the sugarmill balance obtaining the net income of the samples. After this weighing, the sample was unloaded on a tarpaulin (Fig. 3), where separation of the extraneous material and a posterior weighing of the components were determined, coded by: T = free tops; DL = leaves and dry leaves; SO = soil, Ta = remnants of chopped cane not eliminated initially; t = remnants of tops aggregate to chopped cane remnants (Fig. 4); RO = roots (Fig. 5); NO = non-selected extraneous material (Fig. 6).

The total weight of extraneous material, subtracted from the total weight of sample S, furnished the net income of chopped canes, the milling material.

Regarding soil index, the weight considered for calculation was not the originally determined by the balance because this value was referred to soils with a determined moisture content. Therefore, the values considered were for dry soil obtained as described in i.e.

All determination of this study was obtained with two decimal fractions. After the statistical analysis, a rounding up to one decimal fraction is accomplished.
RESULTS AND DISCUSSIONS

Total Extraneous Material Index (TEI\%)

Variance analysis of TEI\% data showed: a) a significant effect (at 1% level of probability) for harvesters and Trials Trials (TT), and b) a non-significant effect for harvester x TT interaction.
The lower and higher values observed for TEI% in TT, shown by harvesters were as follows:

<table>
<thead>
<tr>
<th>Harvesters</th>
<th>Lower and Higher Values of TEI%</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>M1 (SANTAL)</td>
<td>5.5 – 15.6</td>
<td>9.64</td>
</tr>
<tr>
<td>M2 (TOFT)</td>
<td>3.8 – 12.8</td>
<td>7.71</td>
</tr>
<tr>
<td>M3 (MF)</td>
<td>6.7 – 14.9</td>
<td>9.93</td>
</tr>
</tbody>
</table>

LSD (Tukey 5%) = 1.30

Comparisons among means reveal that harvester M2 showed TEI% lower than the other harvesters. Harvesters M1 and M3 were non-significant in relation to TEI%.

Mean values for TEI% observed between TT were as follows:

<table>
<thead>
<tr>
<th>TT</th>
<th>Average TT (3 harvesters)</th>
<th>TT</th>
<th>Average TT (3 harvesters)</th>
</tr>
</thead>
<tbody>
<tr>
<td>R1</td>
<td>8.88</td>
<td>R4</td>
<td>7.14</td>
</tr>
<tr>
<td>R2</td>
<td>11.04</td>
<td>R5</td>
<td>6.26</td>
</tr>
<tr>
<td>R3</td>
<td>13.79</td>
<td>R6</td>
<td>7.45</td>
</tr>
</tbody>
</table>

LSD (Tukey 5%) = 2.30

Comparisons among means reveal that TEI% for the tested harvesters was affected by the trial conditions (differences among TT). In the TT R4, R5 and R6, the lowest values of TEI% were observed.

The non-significant TT x harvester interaction deduces that the harvester performance did not vary from one TT to other. Harvester M2 showed the lowest TEI% indexes in all TT.

Top Index (TI%)

Variance analysis of TI% data revealed: a) a significant effect (at 1% level of probability) for harvesters and Test Trials (TT) and b) a non-significant effect for harvester x TT interaction.

The lower and higher values observed for TI% in TT shown by harvesters were as follows:
Comparisons among means revealed that harvester M3 showed, on the average, a higher T1% than harvesters M1 and M2. Between harvesters M1 and M2, T1% is not defined statistically.

<table>
<thead>
<tr>
<th>Harvesters</th>
<th>Lower and Higher Values of T1%</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>M1</td>
<td>3.3 - 11.0</td>
<td>5.31</td>
</tr>
<tr>
<td>M2</td>
<td>2.0 - 9.2</td>
<td>4.61</td>
</tr>
<tr>
<td>M3</td>
<td>4.2 - 11.2</td>
<td>6.74</td>
</tr>
</tbody>
</table>

$LSD (Tukey 5\%) = 1.06$

Comparisons among means observed for T1% among TT were as follows:

<table>
<thead>
<tr>
<th>TT</th>
<th>Average (3 harvesters)</th>
<th>TT</th>
<th>Average (3 harvesters)</th>
</tr>
</thead>
<tbody>
<tr>
<td>R1</td>
<td>5.54</td>
<td>R4</td>
<td>4.78</td>
</tr>
<tr>
<td>R2</td>
<td>4.74</td>
<td>R5</td>
<td>4.31</td>
</tr>
<tr>
<td>R3</td>
<td>9.94</td>
<td>R6</td>
<td>4.00</td>
</tr>
</tbody>
</table>

$LSD (Tukey 5\%) = 1.87$

Comparisons among means reveal that T1% for the tested harvesters were affected by the conditions of each TT. Comparisons among means reveal that TT R3 showed a higher T1% and was significant in relation to the others. The remaining TT were non-significant between them.

Leaf and Dry Leaf Index (L1%)

Variance analysis of L1% data revealed that a significant effect (at 5% level of probability) for harvesters; for TT (at 1% level of probability) and harvester x TT interaction (at 5% level of probability).

The significant effect for harvester x interaction in the variance analysis took the decomposition of its number of degrees of freedom. The new variance analysis revealed for harvesters only in TT R2 and R6.

The lower and higher values observed for L1% in TT, shown by harvesters were as follows:
Comparisons among means through Tukey test (5% of probability) showed that: a) in the TT R2, the harvester M1 presented a higher LI% than harvester M2. Harvester M3 presented an intermediary performance between M1 and M2 and was non-significant in relation to them; b) in the TT R6, the harvester M3 presented a higher LI% than the others, i.e., presented the worst performance; c) in the remaining tests, non-significant differences among harvesters were shown.

Mean values observed for LI% in TT groups were as follows:

<table>
<thead>
<tr>
<th>TT</th>
<th>Average</th>
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<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>R1</td>
<td>1.59</td>
<td>R4</td>
<td>0.92</td>
</tr>
<tr>
<td>R2</td>
<td>2.03</td>
<td>R5</td>
<td>0.52</td>
</tr>
<tr>
<td>R3</td>
<td>1.29</td>
<td>R6</td>
<td>1.00</td>
</tr>
</tbody>
</table>

$LSD (Tukey 5%) = 1.04$

Root Index (RI%)

The variance analysis of RI% data revealed that: a) a significant effect (at 1% level of probability) among harvesters and for Test Trials (TT); b) a non-significant effect for harvester x TT interaction.

The lower and higher values observed for RI% in TT, shown by harvesters were as follows:

<table>
<thead>
<tr>
<th>Harvesters</th>
<th>Lower and Higher Values of RI%</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>M1</td>
<td>0.2 - 1.2</td>
<td>0.68</td>
</tr>
<tr>
<td>M2</td>
<td>0.0 - 1.0</td>
<td>0.42</td>
</tr>
<tr>
<td>M3</td>
<td>0.1 - 0.7</td>
<td>0.32</td>
</tr>
</tbody>
</table>

$LSD (Tukey 5%) = 0.28$
Comparisons among means through Tukey test (5% of probability) showed that: a) in the TT R2, the harvester M1 presented a higher L1% than harvester M2. Harvester M3 presented an intermediary performance between M1 and M2 and was non-significant in relation to them; b) in the TT R6, the harvester M3 presented a higher L1% than the others, i.e., presented the worst performance; c) in the remaining tests, non-significant differences among harvesters were shown.

Mean values observed for L1% in TT groups were as follows:

<table>
<thead>
<tr>
<th>Harvesters</th>
<th>Lower and Higher Values of L1%</th>
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</tr>
</thead>
<tbody>
<tr>
<td>M1</td>
<td>0.4 – 3.5</td>
<td>1.43</td>
</tr>
<tr>
<td>M2</td>
<td>0.4 – 7.8</td>
<td>1.26</td>
</tr>
<tr>
<td>M3</td>
<td>0.6 – 3.0</td>
<td>1.78</td>
</tr>
</tbody>
</table>

$LSD (Tukey 5\%) = 0.59$

Root Index (RI%)

The variance analysis of RI% data revealed that: a) a significant effect (at 1% level of probability) among harvesters and for Test Trials (TT); b) a non-significant effect for harvester x TT interaction.

The lower and higher values observed for RI% in TT, shown by harvesters were as follows:

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<tbody>
<tr>
<td>M1</td>
<td>0.2 – 1.2</td>
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</tr>
<tr>
<td>M2</td>
<td>0.0 – 1.0</td>
<td>0.42</td>
</tr>
<tr>
<td>M3</td>
<td>0.1 – 0.7</td>
<td>0.32</td>
</tr>
</tbody>
</table>

$LSD (Tukey 5\%) = 0.28$
Comparisons among means revealed that harvester M1 presented, on the average, a higher R1% than the others. Between harvesters M2 and M3, R1% was non-significant.

Mean values observed for R1% among TT were as follows:

<table>
<thead>
<tr>
<th>TT</th>
<th>Average (3 harvesters)</th>
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<th>Average (3 harvesters)</th>
</tr>
</thead>
<tbody>
<tr>
<td>R1</td>
<td>0.26</td>
<td>R4</td>
<td>0.36</td>
</tr>
<tr>
<td>R2</td>
<td>0.68</td>
<td>R5</td>
<td>0.54</td>
</tr>
<tr>
<td>R3</td>
<td>0.22</td>
<td>R6</td>
<td>0.80</td>
</tr>
</tbody>
</table>

LSD (Tukey 5%) = 0.50

The significant effect for TT revealed that R1% for harvesters was affected by the culture conditions of TT. The composition of averages revealed that in the TT R3, a lower R1% average was shown.

The non-significant interaction among harvesters x TT in terms of R1% indicates that the performance among harvesters did not vary from one TT to other, i.e., harvester M1 presented a higher R1% than the remaining in all TT.

**Soil Index (SI%)**

The variance analysis of SI% data revealed that: a) a significant effect (at 1% level of probability) for harvesters, for TT and for harvester x TT interaction.

The significant effect for harvester x TT interaction in the variance analysis took the decomposition of its number of degrees of freedom. The new variance analysis revealed significance for harvesters in the TT R1 and R2. Such a fact indicates a variation of performance among harvesters, in terms of SI%, from one TT to other.

In the TT R1 and R2, the harvester M1 presented a higher SI% than harvester M2. In the remaining TT, there were non-significant differences among harvesters.

The lower and higher values observed for SI% in TT presented by harvesters were as follows:

<table>
<thead>
<tr>
<th>Harvesters</th>
<th>Lower and Higher Values of SI%</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>M1</td>
<td>0.5 – 3.9</td>
<td>1.28</td>
</tr>
<tr>
<td>M2</td>
<td>0.1 – 1.7</td>
<td>0.61</td>
</tr>
<tr>
<td>M3</td>
<td>0.3 – 1.1</td>
<td>0.59</td>
</tr>
</tbody>
</table>

LSD (Tukey 5%) = 0.02
Comparisons among means revealed that harvester M3 presented a lower SI% than the remaining. Harvester M2 and M3 were non-significant between them, but were both significant in relation to M1, which presented the highest SI%.

Mean values observed for SI% between TT were as follows:

<table>
<thead>
<tr>
<th>TT</th>
<th>Average</th>
<th>TT</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>R1</td>
<td>0.32</td>
<td>R4</td>
<td>0.40</td>
</tr>
<tr>
<td>R2</td>
<td>2.18</td>
<td>R5</td>
<td>0.47</td>
</tr>
<tr>
<td>R3</td>
<td>0.56</td>
<td>R6</td>
<td>1.04</td>
</tr>
</tbody>
</table>

LSD (Tukey 5%) = 0.04

Comparisons among means reveal that SI% for the tested harvesters were affected by trial conditions (differences among TT). In the TT R1, R4 and R5, the lower values for SI% were observed.

Non-Selected Material Index (NI%)

Variance analysis of NI% data revealed a significant effect for harvesters, for TT and for harvester x TT interaction (at 1% level of probability). The significant effect for harvester x TT interaction caused the decomposition of its number of degrees of freedom. The new analysis of variance revealed significance for harvesters in the TT R2, R3 and R4, indicating a variation in performance among harvesters, in terms of NI% from one TT% to other.

The lower and higher values observed for NI% in TT, presented by harvesters were as follows:

<table>
<thead>
<tr>
<th>Harvesters</th>
<th>Lower and Higher Values of NI%</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>M1</td>
<td>0.1 – 2.5</td>
<td>0.92</td>
</tr>
<tr>
<td>M2</td>
<td>0.2 – 1.9</td>
<td>0.82</td>
</tr>
<tr>
<td>M3</td>
<td>0.2 – 1.0</td>
<td>0.49</td>
</tr>
</tbody>
</table>

LSD (Tukey 5%) = 0.10

Comparisons among means revealed that harvester M3 presented the lowest NI%, and was significant relating to the remaining. Harvesters M1 and M2 were non-significant between them.

Mean values observed for NI% between TT were as follows:

<table>
<thead>
<tr>
<th>TT</th>
<th>Average</th>
<th>TT</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>R1</td>
<td>0.16</td>
<td>R4</td>
<td>0.68</td>
</tr>
<tr>
<td>R2</td>
<td>0.81</td>
<td>R5</td>
<td>0.45</td>
</tr>
<tr>
<td>R3</td>
<td>1.78</td>
<td>R6</td>
<td>0.57</td>
</tr>
</tbody>
</table>

LSD (Tukey 5%) = 0.34
Comparisons among means revealed that N1% for the tested harvesters was affected by the trial conditions (differences among TT). In the TT R1, R4 and R5, the lowest N1% values were observed.

**Efficacy of Manipulation (EM%)**

The variance analysis of EM% data revealed a non-significant effect among harvesters and for harvester x TT interaction, and a significant effect for TT (at 1% level of probability).

The lower and higher values observed for EM% presented by harvesters were as follows:

<table>
<thead>
<tr>
<th>Harvesters</th>
<th>Lower and Higher Values of EM% (t/h)</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>M1</td>
<td>74.9 - 92.0</td>
<td>84.64</td>
</tr>
<tr>
<td>M2</td>
<td>72.0 - 94.5</td>
<td>84.59</td>
</tr>
<tr>
<td>M3</td>
<td>76.0 - 93.5</td>
<td>84.98</td>
</tr>
</tbody>
</table>

*LSD (Tukey 5%) = 4.59*

Comparisons among means revealed that there was no significant differences among harvesters. All three harvesters had the same performance under the different conditions of all six TT.

The non-significant harvester x TT interaction determines that the performance of harvesters did not vary from one TT to other, i.e., for each TT, all harvesters had the same performance.

The significant effect for TT reveals that EM% for the tested harvesters was affected by the conditions of TT. In the TT R5 and R6, EM% was higher than the remaining TT, despite the non-significant difference which occurred between R5 and R6, as well among the remaining TT.

Mean values observed for EM% among TT were as follows:

<table>
<thead>
<tr>
<th>TT</th>
<th>Averages (t/h) (3 harvesters)</th>
<th>TT</th>
<th>Averages (t/h) (3 harvesters)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>R4</td>
<td>81.33</td>
</tr>
<tr>
<td>R1</td>
<td>83.16</td>
<td>R2</td>
<td>81.60</td>
</tr>
<tr>
<td>R2</td>
<td>82.07</td>
<td>R3</td>
<td>91.58</td>
</tr>
<tr>
<td>R3</td>
<td>78.69</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*LSD (Tukey 5%) = 8.09*
The non-significant harvester x TT interaction indicates that in terms of EM%, there was no variation of performance among harvesters. For each TT, all 3 harvesters had the same performance among harvesters, from one TT to other.

In short, the tested harvesters presented, on the average, EM% values from 75.8 to 93.8, causing losses of milling raw-material from 6.1 to 24.2%.

**Effective Capacity (EC)**

The variance analysis of Effective Capacity (EC) data revealed a significant effect for harvesters and for TT (at 1% level of probability) and for harvester x TT interaction (at 5% level of probability).

The significant effect for harvester x TT interaction took the decomposition of its number of degrees of freedom. The new variance analysis revealed significance to the 1% level of probability for TT R5 and at 5% level of probability for the TT R3 and R6, indicating a variation of performance among harvesters, in terms of one TT to other.

The lower and higher values observed for TT, presented by harvesters were as follows:

<table>
<thead>
<tr>
<th>Harvesters</th>
<th>Lower and Higher Values of EC (t/h)</th>
<th>Average (t/h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>M1</td>
<td>21.2 - 42.8</td>
<td>33.30</td>
</tr>
<tr>
<td>M2</td>
<td>23.4 - 57.6</td>
<td>43.63</td>
</tr>
<tr>
<td>M3</td>
<td>35.3 - 50.0</td>
<td>42.55</td>
</tr>
</tbody>
</table>

\[LSD \text{ (Tukey 5\%)} = 6.44\]

Mean values observed for EC among TT were as follows:

<table>
<thead>
<tr>
<th>TT</th>
<th>Averages (t/h) (3 harvesters)</th>
<th>TT</th>
<th>Averages (t/h) (3 harvesters)</th>
</tr>
</thead>
<tbody>
<tr>
<td>R1</td>
<td>38.81</td>
<td>R4</td>
<td>39.56</td>
</tr>
<tr>
<td>R2</td>
<td>43.42</td>
<td>R5</td>
<td>46.76</td>
</tr>
<tr>
<td>R3</td>
<td>27.04</td>
<td>R6</td>
<td>46.69</td>
</tr>
</tbody>
</table>

\[LSD \text{ (Tukey 5\%)} = 11.38\]

Comparisons among means showed that in the TT R3, a lower EC of harvesters was observed, therefore, there was no significant difference of EC among harvesters.
In the RR R6, it was verified that the harvester M1 presented an EC lower than harvester M2. The performance of harvester M3 was non-significant in relation to harvesters M1 and M2. In the remaining TT, the performance among harvesters, in terms of TT was non-significant.

"Practical" Effective Capacity (EC')

The variance analysis of "Practical" Effective Capacity (EC') data revealed a significant effect for harvesters (at 5% level of probability), and for Test Trials and harvester x TT interaction (at 1% level of probability).

The significant effect for harvester x TT interaction took the decomposition of its number of degrees of freedom. The new variance analysis revealed significance at 1% level of probability in all TT, indicating that the variations of field conditions among TT affected EC' of the harvesters.

The lower and higher values observed for EC' presented by harvesters were as follows:

<table>
<thead>
<tr>
<th>Harvesters</th>
<th>Lower and Higher Values of EC' (t/h)</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>M1</td>
<td>24.8 – 49.0</td>
<td>36.18</td>
</tr>
<tr>
<td>M2</td>
<td>30.6 – 64.8</td>
<td>49.54</td>
</tr>
<tr>
<td>M3</td>
<td>36.7 – 69.8</td>
<td>47.63</td>
</tr>
</tbody>
</table>

LSD (Tukey 5%) = 3.02

Comparisons among means showed that the harvester M1 presented the lowest EC', being significant in relation to harvesters M2 and M3. These were non-significant between them.

Mean values observed for EC' among TT were as follows:

<table>
<thead>
<tr>
<th>TT</th>
<th>Averages (t/h)</th>
<th>TT</th>
<th>Averages (t/h)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(3 harvesters)</td>
<td></td>
<td>(3 harvesters)</td>
</tr>
<tr>
<td>R1</td>
<td>44.46</td>
<td>R4</td>
<td>46.14</td>
</tr>
<tr>
<td>R2</td>
<td>50.27</td>
<td>R5</td>
<td>44.86</td>
</tr>
<tr>
<td>R3</td>
<td>31.07</td>
<td>R6</td>
<td>50.90</td>
</tr>
</tbody>
</table>

LSD (Tukey 5%) = 6.26

Comparisons among means revealed that in the TT R3, the lowest EC' of harvesters was observed and in the TT R6, the highest EC'.

Frequency of Length of Chopped Canes (F%)

The data analysis of length of chopped canes covers the study of distribution of frequencies for each harvester in the last five TT. From these data, polygons of frequency for each harvester were constructed, as shown in Fig. 7. By comparing the polygons, it is observed that the harvester M2 presented a higher variability in the distribution of frequency of length of chopped canes among the remaining TT, than the harvesters M1 and M3.

The intervals of group of length of chopped canes that presented a higher frequency in the TT were as follows:

<table>
<thead>
<tr>
<th>Harvester</th>
<th>Intervals of Group of Higher Frequency (cm)</th>
<th>TT</th>
</tr>
</thead>
<tbody>
<tr>
<td>M1</td>
<td>25 – 30</td>
<td>R2 to R6</td>
</tr>
<tr>
<td>M2</td>
<td>25 – 30</td>
<td>R2, R3 &amp; R6</td>
</tr>
<tr>
<td>M3</td>
<td>20 – 25</td>
<td>R4, R5</td>
</tr>
<tr>
<td></td>
<td>25 – 30</td>
<td>R2 to R6</td>
</tr>
</tbody>
</table>

The results showed that harvesters M1 and M3 presented a very satisfactory uniformity, on the contrary to M2.

CONCLUSIONS

Total Extraneous Material Index (TEI%)

Harvester M2 presented the lowest TEI%, independently of trial conditions.
The TEl% values presented by harvesters M1 and M3 were non-significant between them. Due to differences of TT, variations of trial conditions affected the TEl% value presented by the tested harvesters. From all previous conclusions, it is evident that the harvester M2 presents more efficient cleaning mechanisms than the others. The cleaning mechanisms of harvesters M1 and M2 are equivalent. In all harvesters, the cleaning performance is affected by the variation of field conditions.

**Top Index (TI%)**

Harvester M3 presented the highest TI%, independently of trial conditions. The values of TI% presented by harvesters M1 and M2 were non-significant between them. Due to differences of TT, variations of trial conditions affected the value of TI% presented by harvesters.

From previous conclusions, harvesters M1 and M2 showed better conditions of top elimination than harvester M3.

**Leaf and Dry Leaf Index (LI%)**

Harvester M2 presented an intermediary LI% between harvesters M1 and M3. Harvesters M1 and M3 appear to be susceptible to field conditions in the different TT; it was observed that TT R2 presented a higher LI% than harvester M1 and in TT R2, higher LI% for harvester M3.

**Root Index (RI%)**

Harvester M1 presented a higher RI%, independently from trial conditions. Values of RI% presented by harvesters M2 and M3 were non-significant. Due to TT, variation of trial conditions affected the RI% value presented by the tested harvesters.

From previous conclusions, it is evident that harvesters M2 and M3 showed mechanism of basal cutting adapted to conditions under which trials in relation to harvester M1 were carried out. There were no differences in performance between harvesters M2 and M3.

**Soil Index (SI%)**

Harvester M1 presented in two of the TT a higher SI% than the remaining and in the other TT, a performance similar to the harvesters M2 and M3.

**Non-Selected Material Index (NI%)**

Harvester M3 presented in two of the TT a lower NI% than the remaining and in the other TT a similar performance to the harvesters M2 and M1.

The harvesters were non-significant among them in all TT regarding Efficacy of Manipulation (EM%). EM% presented significant variations under the different field conditions favored by all TT.
It is evident, therefore, that EM% varies depending upon the field conditions, when harvesters are conducted by properly experienced operators.

Effective Capacity (EC) of harvesters were affected by field conditions; in the TT R3, EC of harvesters was lower than the remaining RR. The harvester M1 presented a lower EC than harvesters M2 and M3. It was observed that EC of harvesters M2 and M3 were non-significant.

"Practical" Effective Capacity had the similar behavior as Effective Capacity (EC). In the TT R3, EC' of harvesters was lower than the remaining TT. The harvester M1 presented a lower EC' than others.

Harvesters M1 and M3 presented the lowest variability in the distribution of frequency of length of chopped canes (F%) in the last five TT. The lowest frequency of length of chopped canes was between 25 – 30 cm.

REFERENCES


EVALUACION DE ALGUNOS PARAMETROS DE FUNCIONAMIENTO DE TRES COSECHADORAS COMBINADAS DE CAÑA DE AZUCAR (SACCHARUM SPP.) IN ALAGOAS, BRAZIL

Ira. PARTE

T.C. Ripoli and L.G. Mialhe

RESUMEN

Con el fin de evaluar la calidad de materia cruda sumida, las cosechadoras combinadas SANTAL—115 (M1), TOFT R—300 (M2),
y MF–201 (M3) fueron sometidas a seis pruebas de comprobación en campos de condiciones similares. Se usó la variedad Co331, Caña erecta, sembrada en hileras espaciadas a 1.40 m, con una variación de densidad de tallos por hilera de 4.47 a 16.85 kg/m. Al tiempo de la prueba el terreno era Latosol Rojo Amarillo, en su fase arenosa, y textura natural de agrupación arenosa con gradiente de campo menor de 2% y variación de humedad del terreno de 5.09 a 9.85% al tiempo de la prueba. De los datos obtenidos de la prueba se determinó lo siguiente. Indice Total de Materia Extraña (%ITME); Indice Superior (%IS); Indice de Hojas y Hojas Secas (%HS); Indice de Raíz (%IR); Indice de Terreno (%IT) e Indice de Material No Seleccionado (%IN). El análisis estadístico de valores encontrados incluyó comparaciones entre medios del método Tukey. Cada índice fue analizado por separado, verificando los efectos de la cosechadora en la Prueba de Comprobación e interactivo en la cosechadora x TT.

Los índices de medios obtenidos (Tukey 5%) por las cosechadoras son como sigue:

M1 (%ITME = 9.64; %IS = 4.61; %HS = 1.43; %IR = 0.68; %IT = 1.28; y %IN = 0.92);

M2 (%ITME = 7.71; %IS = 4.61; %HS = 1.26; %IR = 0.42; %IT = 0.61 y %IN = 0.82; y

M3 (%ITME = 9.93; %IS = 6.74; %HS = 1.78; %IR = 0.32; %IT = 0.59 y %IN = 0.49).