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Comparative performance of commonly used portable coffee harvesters

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In mountain regions due to the high slopes, the coffee harvest is carried out manually, generating higher production costs. An alternative to reducing these costs is to use portable breakers. The objective of this work was to evaluate the efficiency of portable coffee breakers in coffee harvesting. The experiment was carried out in a field of Catucaí Amarelo 24/137, 3.5 years old. In the study, six types of breakers were tested, in addition to an extra treatment, the experiment was delineated in randomized blocks with four replicates. The number of broken coffee, remaining coffee, number of broken branches that fell on the melting cloth, number of primary and secondary branches present in the plants and defoliation were evaluated. The commercial bruising Brudden promoted a greater amount of broken branches fallen in the cloth of derrick. Regarding the defoliation, it was observed that the Brudden melt promoted the highest values, followed by commercial brands AGS Dupla, Nakashi and Sthil WR9. The treatments Sthil WR6 / 2 and WR6, and Sthil associated to the rubber extensors obtained the lowest values of defoliation. Brudden was also the one that promoted the largest amount of broken branches accounted for in the plant. Based on that, results showed that harvest process using portable milling machines has high harvesting efficiency.

Key words: Operational efficiency, defoliation, *Coffea arabica.*

INTRODUCTION

Brazil is the world's largest producer of coffee for 150 years, being that this product is mainly responsible for the economic strengthening of the country. Over the years, the management of crops has been changing until reaching the molds of today, with greater population density, the coffee plants approach in the line and

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separation between lines to enable the mechanization. The profit of the activity is closely linked to the possibility of mechanization of operations (Santinato et al., 2015). In flat and undulating areas, harvesting can be done with harvesters, but in more steep areas there must be alternatives to increase the operational performance of manual operators.

In Brazil, the substitution of manual harvesting by mechanized alternatives has become evident and extensive in the last 30 years (Matiello et al., 2015). Nevertheless, it is impossible to use harvesters (trawlers or self-propelled), in some large areas with slopes, similar to what happens in other producing countries from Central America like Colombia (Cárdenas et al., 2015; Santinato et al., 2016a; Tavares et al., 2016). In addition to that, coffee harvesters (trawlers or self-propelled) are complex machines (Silva et al., 2018) with high cost and components often subjected to vibrations (Souza et al., 2018), increasing maintenance costs. Due to the high cost of alternatives for manual harvesting (Santinato et al., 2015) the use of manual harvesting machines has experienced an upsurge, which reduce labor cost and have considerable superior operational field capacity to that of harvesting by hand (Barbosa et al., 2005; Souza et al., 2005, 2006).

Plant damage is one of the drawbacks of semi-mechanized harvesting (using manual harvesters), especially for young plants (Barros et al., 1995); however, there is controversy regarding the use of portable harvesters, and there are still controversies, lacking this data. Santinato et al. (2016a) reported a substantial reduction in plant damage via the use of flexible extenders at the tip of coffee harvesters' rods. Plant damage might be further reduced by adapting such extenders at the tip of portable harvesters' rods. Consequently, the objective of this study was to evaluate the efficiency of portable harvesters used with flexible extensors and their morphological effects in coffee plants.

MATERIALS AND METHODS

The experiment was carried out at Fazenda São Lourenço in the municipality of Manhuaçu, in the Zona da Mata region of Minas Gerais. Coffee trees of the Catucaí Amarelo cultivar 24/137 aged 3.5 years (second crop) were planted in a humic Oxisol (LVh) at 2.8 × 0.80 spacing in a slope of 18% and in dry conditions.

In this study, six types of manual harvesters (the most used portable coffee harvesters) were tested. Moreover, we included an additional treatment to test whether portable coffee harvesters with rubber extenders at the tip of rods would generate a faster, larger, safer (for the plant) harvest than that of harvesters without extenders (Figure 1).

Figure 1. Flexible extenders placed at the tip of the portable derriere rods.

We evaluated Shindaiwa 230 engine and double Brudem derrick (T1); Stihl KA 85 engine and Stihl WR6 / 2 derrick (T2); Stihl KA 85 engine and Stihl WR6 derrick (T3); Stihl KA 85 engine and Stihl WR9 derrick (T4); Husqvarna 226 engine and double AGS derrick (T5); Mitsubish engine and Nakashi melter (T6) and Sthil KA85 engine and Sthil WR6 more extensors (T7), and more information and technical specifications of the equipment can be obtained in their commercial catalogs. The seven treatments were carried out in randomized blocks, with four replicates and eight plant plots. The experiment began on July 3, 2017, and on this date the crop presented 6.64 L per plant. In this date, the fruits observed were in distinct stages of maturation: 26, 47 and 27% were in the green, cherry, and dry maturation stages, respectively.

The present study evaluated the amount of harvested coffee, remaining coffee, number of broken branches fallen in the harvest cloth, number of primary and secondary branches on the plant, and operational defoliation (leaves that have fallen in the harvest cloth) following the methodology of Santinato et al. (2014). Furthermore, the coffee brewing time and the harvest time per plant were measured, and then, the proportional amount of time required to brew one liter of coffee was calculated. Finally, the data were submitted to analysis of variance (ANOVA) and when applicable to Duncan's test, both were at 5% probability.

RESULTS AND DISCUSSION

Among all of the tested harvesters, the Brudden model caused the largest number of broken branches that have fallen on the cloth, significantly higher than that of other models. This could be attributed to its structure, because the rods have bifurcations that may break the branches depending on the movements performed by the operator; increasing the oscillation angle of the adjacent plates supporting the rods might consequently overcome this issue. Notably, the differences among the other harvester models were not statistically significant. Nonetheless, there was a trend for reduced damage by the Sthil WR6 model, and a noticeable tendency for a lower number of broken branches when using rubber extenders in splitter rods' tips, which reduced the amount for 9.56 branches only.

The operational defoliation values were the highest for the Brudden harvester, followed by the AGS Dupla, Nakashi, and Sthil WR9, whereas the lowest values were obtained using harvesters with rubber extensors, namely, Sthil WR6-2 and WR6, and Sthil. This suggests that double harvesters promote greater operational defoliation than simple harvesters.

Brudden also produced the largest number of broken branches accounted for in the plant. In the background, AGS Dupla, Nakashi, and Sthil were used with rubber extensors. The Sthil harvester with the rubber extensors installed has a small distance between its rods, requiring the operator to force the harvester into the plant and therefore causing several branches to break. Despite breaking only a small number of branches off the plant, this harvester produced a large amount of broken primary branches. This was because only the green, living branches that have fallen in the cloth were considered, as the weak, dry branches in the plant were already counted.

The highest number of broken secondary branches in the plant was produced by the Nakashi harvester followed by the AGS Dupla and Brudden. The other harvesters generated insignificant amounts of broken secondary branches.

Reduction of the number of nodes reflects a reduction in productivity (Martinez et al., 2007). When measuring this, Barros et al. (1995) obtained higher values of broken branches than those of the present experiment, which demonstrates that portable harvesters have evolved and improved.

The values for functional defoliation were lower than those obtained in experiments comparing manual harvesting against mechanized harvesting (Silva et al., 2010; Santinato et al., 2015). Plant defoliation reduces the capacity of plants for active synthesis, which affects and reduces coffee productivity (DaMatta et al., 2007).

Santinato et al. (2016b) indicated that reduction of plant defoliation when harvesting with rubber extenders is caused by the materials being less rigid than those of the harvester (fiberglass or plastic rods). Damage done to the plant's bark was an observed but unmeasured aspect; because of their relatively smooth surface, rubber extenders did not damage the bark of coffee trees (Figure 2), whereas the other treatments evidently did. Damage to the branches' bark is a gateway for pests and diseases and promotes lower sap circulation, which culminates in drought of the branches or dieback (Malavolta et al., 2002). Considering that the higher the productivity, the greater the defoliation and the breakage of branches (Souza et al., 2006), it is worth noting that the experiment was carried out in a high-productivity field. Therefore, it is estimated that the values may be even lower in plants with lower crop load than those obtained herein (Table 1).

The amount of coffee harvested did not differ significantly between treatments, although it varied from 5.72 to 7.38 L per plant. This variation is attributed to the normal variability of coffee plants within the experimental area. Additionally, the amount of remaining coffee ranged from 0.14 to 0.27 L per plant. It was predominantly green and protected by branches either close to the trunk, the upper third, or the lower third, making it difficult to access and hampering the equipment's ability to harvest. The smallest amounts of remaining coffee were obtained using AGS Dupla, Nakashi, and Sthil harvesters with rubber extenders. Regarding the amount of coffee present in the feet, the amount of coffee remaining ranged from 1.97 to 4.1%. The other values of the remaining coffee were attributed to Sthil treatments, in all models. The AGS Dupla harvester generated the least remaining coffee, which consequently increased the harvesting efficiency. The utilization of rubber extensors at the rods' tip optimized the operation of Sthil harvesters, as seen in the Sthil KA85 engine and Sthil WR6 more extensors (T7 treatment); thus, it may be a viable solution to overcome this problem. Extenders may be used in other types of portable harvesters, such as those utilized in Colombia where harvesting is entirely labor-dependent (Cárdenas et al., 2013; Mejia et al., 2013; Cárdenas et al., 2015).

Barros et al. (1995) pointed out quantities of 10% remaining coffee after harvesting using markers. This fact also shows an evolution in the efficiency of the machines to see the smallest amount of coffee remaining in the plants, in all treatments, even if there were significant amount of green fruits in the plants. It is worth noting that the results could be relatively high for crops with fewer green fruits than ripe fruits, as green fruits are strongly retained in the branches (Silva et al., 2013).

Santinato et al. (2016b) described that rubber extenders increase the harvesters' efficiency because of their proximity to the fruits near the trunk of the coffee tree, so that the contact area is increased. Since the oscillation of flexible extenders is relatively high, this potentiates the operation and consequently augments the total coffee harvested in a given amount of time. When using this harvesting system, the amount of remaining coffee is small and therefore should not be considered problematic, especially considering that a well-trained operator could manually collect any remaining fruits in sight.

Double presentation produced the best results with respect to harvesting speed, while the harvester Sthil WR6/2 (T2) required the longest time. The use of rubber extenders failed to significantly reduce the amount of time required for harvest. However, all treatments were faster

Figure 2. Branch by the portable cutter without the rubber extenders.

Table 1. Number of broken branches per plant dropped on the melting cloth, operational defoliation and number of broken primary and secondary branches present in the plant after application of the treatments, Manhuaçu, 2017.

Treatment	Number of broken branches per plant collected on the ground cloth	Defoliation	Number of broken branches per plant	
		kg plant^{-1}	Primary	Secondary
Shindaiwa 230 engine and double Brudem derrick	22.16^{b}	0.73^{b}	2.69^{b}	4.81^{b}
Stihl KA 85 engine and Stihl WR6 / 2 derrizer	13.44^{a}	0.45^{a}	1.19^{a}	1.38^{a}
Stihl KA 85 engine and Stihl WR6 derrick	11.78^{a}	0.47^{a}	0.91^{a}	1.38^{a}
Stihl KA 85 engine and Stihl WR9 derrizer	12.63^{a}	0.54^{ab}	1.06^{a}	1.63^{a}
Husqvarna 226 engine and double AGS derrick	14.38^{a}	0.66^{ab}	2.13^{ab}	5.19^{b}
Mitsubish engine and Nakashi melter	14.22^{a}	0.62^{ab}	2.0^{ab}	3.31^{ab}
Sthil KA85 engine and Sthil WR6 more extensors	9.56^{a}	0.44^{a}	1.88^{ab}	1.88^{a}
CV (%)	32.71	25,22	46,38	51.73

*Averages followed by the same letters do not differ from each other, in the columns, by the Ducan test at 5% probability.

Table 2. Coffee harvested and remaining per plant, remaining coffee as a function of the pending load, harvest time to harvest each plant and each liter of coffee, Manhuaçu, 2017.

Treatment	Coffee harvested	Coffee remaining in the plant		Break time	
	L plant^{-1}	L plant^{-1}	%	s plant^{-1}	s L^{-1}
1 - Shindaiwa 230 engine and dual Brudden derrick	7.38^{a}	0.22^{ab}	2.92^{ab}	26.38^{a}	3.57^{ab}
2 - Stihl KA 85 engine and Stihl WR6 / 2 derrizer	5.72^{a}	0.23^{ab}	4.1^{b}	27.03^{a}	4.93^{c}
3 - Stihl KA 85 engine and Stihl WR6 derrick	6.16^{a}	0.23^{ab}	3.91^{b}	26.19^{a}	4.42^{bc}
4 - Stihl KA 85 engine and Stihl WR9 derrizer	6.94^{a}	0.27^{b}	3.92^{b}	25.06^{a}	3.68^{ab}
5 - Husqvarna 226 engine and double AGS derrick	7.44^{a}	0.14^{a}	1.97^{a}	20.78^{a}	2.8^{a}
6 - Mitsubish engine and Nakashi melter	6.81^{a}	0.14^{a}	2.32^{ab}	23.03^{a}	3.51^{ab}
7 - Sthil KA85 engine and Sthil WR6 more extensors	6.06^{a}	0.16^{a}	2.51^{ab}	25.94^{a}	4.28^{bc}
CV (%)	29.89	29.14	36.57	25.89	15.59

*Averages followed by the same letters do not differ from each other, in the columns, by the Ducan test at 5% probability.

than manual harvesting, which takes eight times as long

(Barbosa et al., 2005) (Table 2).

Conclusions

1. In general, all portable harvesters have a high harvesting efficiency. They leave a maximum of 4.1% of the load at the feet, which could be manually picked by the operator simultaneously; thus, transfer is not required. The use of rubber extenders at the rods' tips increases harvesting efficiency.
2. Damage caused by portable harvesters is extremely variable among different models. From this study, it could be inferred that double-handed hammers cause more damage than single-handed hammers. The Brudden harvester produced the greatest damage as indicated by most of the parameters evaluated in this study. The use of rubber extenders at the rods' tips reduced plant damage.
3. Double-handed harvesters reduced the amount of time required to harvest coffee.
4. The use of rubber extenders at the end of the harvesters' rods prevented most of the damage to the bark of the branches, which would have favored plant disease.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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