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Mechanized harvesting of conilon coffee plants using a self-propelled machine[1]

Colheita mecanizada de plantas de café conilon utilizando uma máquina automotriz

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HIGHLIGHTS:

The increase in speed from 800 to 1600 m h^{-1} reduced harvesting efficiency from 79.3 to 55.0% and defoliation by 52.0%.
Conilon with two orthotropic branches and the removal of part of plagiotropic branches increased harvesting efficiency.
Mechanized harvesting of Coffea canephora reduced harvesting costs by over 79% compared to manual harvesting.

ABSTRACT: Coffee is one of the main commodities of global agribusiness and of outstanding economic and social relevance for Brazil. The lack of labor and its high cost are factors that worry coffee producers, mainly during the conilon coffee harvesting, which is performed manually. This study aimed to evaluate the efficiency of a self-propelled harvester under different conditions of machine adjustment and conduction of the *Coffea canephora* crop and measure its influence on the cost of harvesting compared to manual harvesting. Harvesting speed (800 to 1600 m h^{-1}), rotation of the vibrating rod cylinder (1.0 and 1.5 RPM), number of orthotropic branches (one, two, and three), and plants with and without plagiotropic branches in the lower third were assessed. The increase in harvesting speed reduced the efficiencies of stripping and harvesting and defoliation. Increasing from one to three orthotropic branches per plant increased harvesting and stripping efficiencies, fruit loss on the ground, defoliation, and reduced pending load. The management without plagiotropic branches showed higher harvesting efficiency, lower loss on the ground, and lower defoliation. Harvesting speeds from 800 to 1600 m h^{-1} reduced the total and unit costs up to 62% compared to manual harvesting. Increasing harvesting efficiency above 70% has reduced harvesting costs by up to 79% compared to manual harvesting.

Key words: *Coffea canephora*, agricultural mechanization, coffee stripping, fruit loss on the ground, harvesting costs

RESUMO: O café é uma das principais commodities do agronegócio mundial e de grande relevância econômica e social para o Brasil. A falta de mão de obra e seu alto custo são fatores que preocupam os cafeicultores, principalmente na colheita do café conilon, feita manualmente. O objetivo deste trabalho foi avaliar a eficiência de uma colhedora automotriz em diferentes condições de ajuste da máquina e condução da lavoura de café conilon e medir sua influência no custo de colheita comparada a colheita manual. Foram avaliados os fatores velocidade de colheita (800 a 1600 m h^{-1}), rotação do cilindro vibrador de varetas (1,0 e 1,5 RPM), número de ramos ortotrópicos (um, dois e três) e plantas com e sem os ramos plagiotrópicos no terço inferior. O aumento da velocidade de colheita reduziu as eficiências de derriça e de colheita e a desfolha. O aumento de um para três ramos ortotrópicos por planta aumentou as eficiências de colheita e de derriça, a perda de chão e a desfolha e reduziu a carga pendente. O manejo sem os ramos plagiotrópicos apresentou maior eficiência de colheita, menor perda de chão e menor desfolha. As velocidades de colheita de 800 a 1600 m h^{-1} reduziram os custos totais e unitários em até 62% em relação à colheita manual. O aumento da eficiência de colheita acima de 70% reduziu os custos de colheita em até 79% em relação à colheita manual.

Palavras-chave: *Coffea canephora*, mecanização agrícola, derriça do café, perda de frutos no solo, custos de colheita

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Introduction

Coffee (*Coffea* spp.) is one of the main commodities of global agribusiness, with an economic impact of US$ 91 billion annually and involving half a billion people (Veloso et al., 2020). Brazil is the world's largest coffee producer, with 47.7 million bags, and the largest grain exporter (Veloso et al., 2020; CONAB, 2022). The two main species cultivated in the world and Brazil are arabica coffee (*C. arabica*) and conilon and robusta (*C. canephora*) (Veloso et al., 2020), with the state of Espírito Santo being the largest national producer of *C. canephora* and the world's second-largest producer (Silva et al., 2019). However, the lack of labor and its high cost are factors that worry coffee producers. Most of the management practices carried out in the fields are manual, and harvesting is the one that requires the highest number of workers (Souza et al., 2020a).

Mechanized harvesting has been carried out efficiently and economically for arabica coffee using self-propelled or tractor-drawn machines with a vibrating rod harvesting system (Santinato et al., 2014, 2015a; Tavares et al., 2019; Kasama et al., 2021). Mechanized harvesting of arabica coffee fruits can reduce harvesting costs by 42 to 62% compared to manual harvesting (Lanna & Reis, 2012; Santinato et al., 2015a). Mechanized stripping occurs through contact with the rods or the vibration transmitted by them to the plant (Villibor et al., 2016; Ferreira Júnior et al., 2020). Mechanized harvesting of conilon coffee has not yet occurred in practice in producing regions due to adjustments required by morphological and plant management differences relative to arabica coffee (Souza et al., 2020a). For example, fruits of *C. canephora* do not detach from the plant with ripening, as with *C. arabica* (Barros et al., 2018).

Variations in the adjustment of harvesters change harvesting efficiency and are necessary for each crop condition (Santinato et al., 2015a; Ferreira Júnior et al., 2020; Kasama et al., 2021), which influences plant damage and defoliation (Santinato et al., 2014). This study aimed to evaluate the efficiency of a self-propelled harvester under different conditions of machine adjustment and conduction of the *Coffea canephora* crop and measure its influence on the cost of harvesting compared to manual harvesting.

Material and Methods

Field tests were carried out in a commercial conilon coffee (*Coffea canephora* Pierre ex. Froehner) crop. The area is located in the Coastal Tablelands geoenvironmental unit (Cavalcanti et al., 2020), in the municipality of São Mateus, northern Espírito Santo state (18° 43' 34.5" S and 40° 00' 28.2" W and 72 m altitude), with a flat topography. The climate in the region is Aw according to the Köppen-Geiger's classification, with an annual rainfall of 1,313 mm and an average annual temperature of 24.1 °C.

The experimental area was installed in 2012 and has 5.44 ha with clonal plants at a spacing of 3.50 × 0.50 m (5,714 plants ha^{-1}) after soil fertility correction. The area was managed with sprinkler irrigation. The planting rows were composed of the 'Bamburral' clone alternated with a mixture of the '153' and '143' clones in the same row. The tests were carried out in July 2017. The average productivity was 10.8 L per plant.

A self-propelled harvester (CaseIH, Coffee Express 200, Piracicaba, Brazil) was used in the tests (Figure 1). The harvester has three driving wheels driven by hydraulic motors, with an internal combustion engine of 75 hp and a 75-L fuel tank. The harvester has two vertical vibrating cylinders with 864 rods each arranged in parallel horizontally and retractable harvester blades with tilt adjustment for receiving the fruits, a 2000-L grain tank, and a side unloading system (Figure 1A). Dimensions are 3290 mm between the axles of the wheelset, 1400 mm between the axles of the agitators, 5730 mm in total length, 3685 mm in total height, 500/60 – 15.5 tires, and a total weight of 6900 kg. It moves over the plants, which are in contact on the sides with the orthotropic branches that vibrate and drop the fruits through the impact and vibration transmitted to the plant (Villibor et al., 2016; Ferreira Júnior et al., 2020).

The factors and treatments evaluated in this study were harvester travel speed (800, 1000, 1300, and 1600 m h^{-1}),

A. B. C. D.

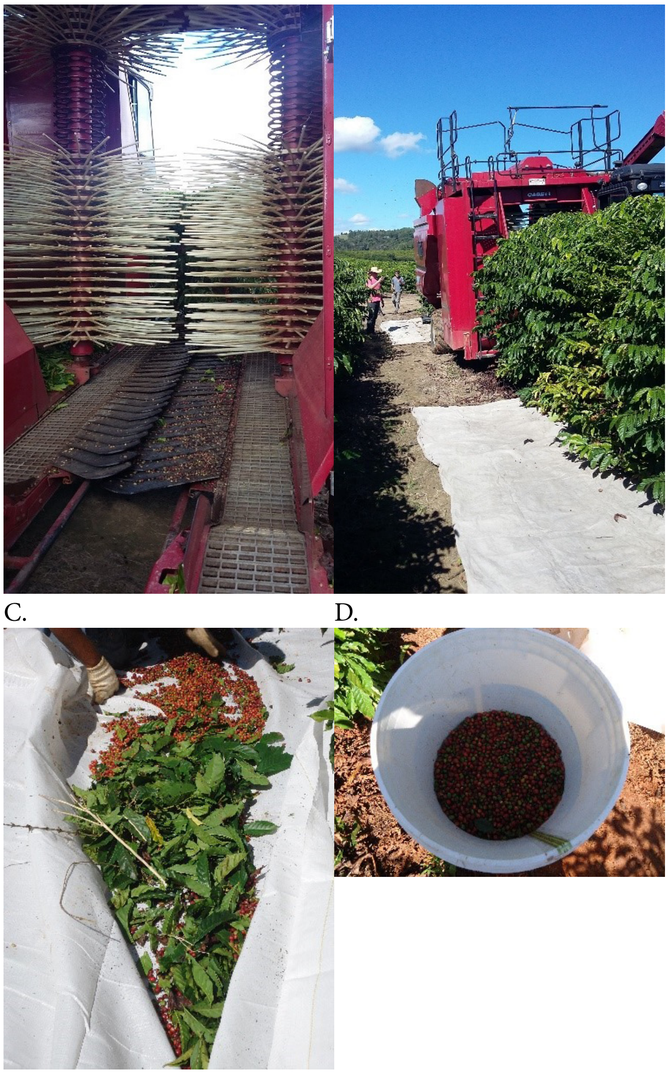


Figure 1. Self-propelled harvester used in the tests with detail of the unit of stripping and receiving the fruits (A), the cloths on the soil (B), the cleaning of fruits left on the cloths, but which would go to the ground (C), and measurement of fruit volume (D) in São Mateus, Brazil

rotation of the vibrating rod cylinder (1.0 and 1.5 RPM), number of orthotropic branches of the coffee tree (one, two, and three) and plants with and without the plagiotropic branches in the lower third. The vibration frequency of the railcar flanges used in the tests was 1000 RPM. The travel speed at harvesting was measured on the machine's speedometer and using a minimum distance of 15 m from harvesting to stabilize the speed. The rotation of the vertical cylinder, containing the vibrating flanges, was adjusted before and at the end of each test. The number of orthotropic (vertical) branches and the presence and absence of plagiotropic (horizontal) branches in the lower third of the plants were defined shortly after the previous harvesting in 2016.

The evaluations for each factor, separately, were carried out in four to eight rows of coffee plants, with three replicates in plots randomly distributed in the rows, analyzing 10 continuous plants, and using a completely randomized design. Clone productivity was measured in three representative plants per plot. Two cloths measuring 2.50 × 6.00 m were spread over the soil in three places on each side of the planting row before mechanized harvesting to measure the loss of fruits on the ground and fruits not stripped (Figures 1B and C) (Santinato et al., 2015a, 2015b). Fruit measurements were performed by volume, using a 20-L (Figure 1D) graduated bucket (Souza et al., 2020a).

After the harvester passes, the fruits can be: (i) stripped from the plant and harvested by the machine, (ii) stripped from the plant and lost in the soil, and (iii) not stripped, that is, they remain attached to the plants. Harvesting efficiency was measured by the percentage of fruit stripped relative to plant productivity (Tavares et al., 2019; Souza et al., 2020a). Fruit harvesting efficiency, loss on the ground, and fruits not stripped were obtained in percentage, considering the fruits harvested by the machine, the fruits lost on the ground, and the fruits that remained attached to the plant, respectively, relative to the plant productivity (Santinato et al., 2015b; Tavares et al., 2019; Souza et al., 2020b). Defoliation was measured in the fresh mass present on the tarpaulins after the passage of the self-propelled harvester, using a portable digital scale (Souza et al., 2020a).

The survey of technical indices allowed calculating the operational cost of mechanized harvesting (US\$ h^{-1}) from the fixed and variable costs, adapted from Pacheco (2000) and Santinato et al. (2015a), using price and cost information for the year 2021 and an exchange rate of US\$ 1.00 = R\$ 5.57. Machine depreciation was measured by the straight-line method, considering a unit value of US\$ 125,673.25, the useful life of 10 years, use of 800 hours per year, and a residual value of 10% (Pacheco, 2000; Santinato et al., 2015a). The interest rate considered was 8.5% per year. The insurance and accommodation rates were 1.0% of the harvester value. Fuel and lubricant consumption was obtained from the harvester manufacturer. The fuel (diesel) value was US\$ 0.87 L^{-1}, the state average on 10/23/21 (ANP, 2021). The maintenance cost was 100% of the purchase price of the machine (Pacheco, 2000). The cost of the operator's salary was US\$ 231.35 per month plus charges (37%).

The total cost of mechanized harvesting (US\$ ha^{-1}) was calculated for speeds from 800 to 1600 m h^{-1} and harvesting efficiency ranging from 60 to 90%, according to the obtained results, and crop yields ranging from 60 to 140 bags ha^{-1} (3600 to 8400 kg ha^{-1} of processed grains). The total cost was obtained by adding up the costs of harvesting, check of soil and plant, and losses on the ground, adapted from Souza et al. (2020b). The harvesting cost was calculated from the operational capacity and operational cost, adapted from Santinato et al. (2015a) and Souza et al. (2020b). The operational capacity was calculated based on the harvesting speed, adding 20% to the maneuvering time on the earth roads (Pacheco, 2000; Souza et al., 2020b). The harvesting of fruits not removed from the plants by the harvester was performed manually at the cost of US\$ 4.49 per bag (80 L) plus taxes. The cost of taking the fruits from the ground was US\$ 179.53 ha^{-1}, based on the price of renting machines used to collect arabica coffee from the ground.

The unit cost (US\$ per bag) was obtained by the relationship between the total cost and productivity (bags ha^{-1}). A ratio of 4.0 bags of fruits (80 L) to produce 1.0 bags of processed grains (60 kg) was used in the calculations, adapted from Souza et al. (2020b). The cost of manual harvesting was US\$ 2.15 per bag (80 L), plus charges, according to the values collected in the north of Espírito Santo. The workers' average harvesting yield was 16 bags (1,280 L) per day and a working day of eight hours a day. The data were collected in the region where the tests were performed.

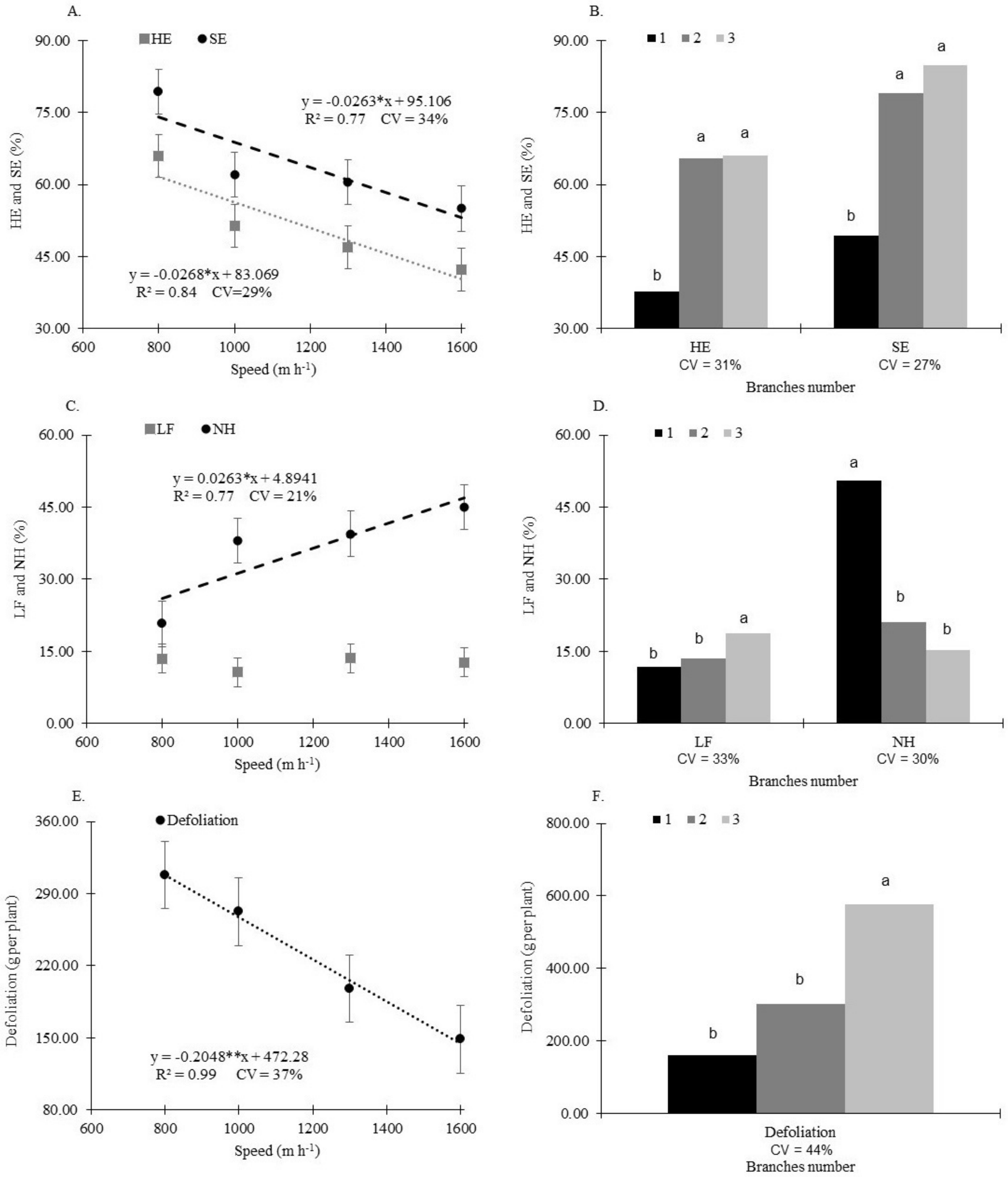
The data from technical evaluations related to the performance of the mechanized harvester were subjected to analysis of variance, followed by regression analysis for harvesting speed and mean tests (F and Tukey tests, $p \leq 0.05$) for the number of orthotropic branches, cylinder rotation containing the vibrating rods, and the presence of plagiotropic branches in the lower third of the plants using the R Core Team (2017) program.

Results and Discussion

The increase in speed influenced the efficiency of the *Coffea canephora* fruit harvesting process. The increase in harvesting speed from 800 to 1600 m h^{-1} reduced the stripping efficiency from 79.32 to 54.99%, harvesting efficiency from 65.88 to 42.32%, and defoliation from 307.85 to 148.58 g per plant (Figures 2A, C, and E). The increase in speed raised the percentage of fruits not stripped from 20.68 to 45.01%, but it did not influence the fruit loss on the ground, ranging from 10.68 to 13.57%.

The percentage of harvested, stripped, and not stripped fruits and defoliation presented linear regression models. The fruit loss on the ground was not influenced by the travel speed, with an average value of 12.59% (Figure 2C).

The increase in harvesting speed resulted in an increase in the operational capacity of the machine from 0.23 to 0.47 ha h^{-1}, which promoted a yield of 3.73 ha per day, agreeing with Pacheco (2000). Tavares et al. (2019) observed lower values of operational capacity in the mechanized harvesting of arabica coffee, with 0.11 ha h^{-1} and 23.07% of time spent with maneuvers and unloading in sloping areas. Harvesting the same area manually would require 58 workers, with an average



** and * - Significant at p ≤ 0.01 and p ≤ 0.05 by the F test. Bars - Mean standard error. Means followed by the same letters do not differ statistically by the Tukey test at p ≤ 0.05

Figure 2. Harvesting (HE) and stripping (SE) efficiencies, fruit loss on the ground (LF), non-harvested fruits (NH), and defoliation of *Coffea canephora* plants in function of harvester travel speeds (A, C, E) and in function of number of orthotropic branches (B, D, F)

harvesting yield of 16 bags (1,280 L) per person. Tavares et al. (2019) also observed a similar result, in which 36 workers were required related to the lower operational capacity caused by the greater time spent on maneuvers due to the field slope.

The increase in speed decreased the contact time of the harvester's vibrating rods with the plant canopy, reducing harvesting and stripping efficiency. The longer machine-plant contact time due to the lower speed of the self-propelled machine increased defoliation, in agreement with Souza et al. (2020a). The reduction of leaf area can reduce plant growth and productivity, as leaf area influences fundamental plant activities, such as light interception, photosynthetic efficiency, evapotranspiration, and response to fertilizers and irrigation (Mbuge & Langat, 2008; Colodetti et al., 2020). Selecting clones more adaptable to the characteristics of mechanized harvesting is necessary to maintain the longevity and sustainability of this mechanized activity (Silva et al., 2013; Souza et al., 2020a).

The increase from one to three orthotropic branches per plant resulted in an increase in harvesting efficiency from 37.73 to 65.53% and stripping efficiency from 49.42 to 79.01% (Figure 2B). However, the increase from two to three orthotropic branches showed no statistical difference, with harvesting efficiency ranging from 65.53 to 66.00% and stripping efficiency from 79.01 to 84.79%. Fruit loss on the ground did not differ statistically in treatments with one and two orthotropic branches, ranging from 11.69 to 13.49%, but an increase was observed with three branches, reaching 18.79% (Figure 2D).

The percentage of fruits not stripped decreased with an increase of orthotropic branches from one to two, ranging from 50.58 to 20.99%. However, treatments with two and three orthotropic branches did not differ statistically. The treatment with three orthotropic branches showed higher defoliation, reaching 576.94 g per plant, not differing between treatments with one and two branches, which ranged from 161.33 to 302.00 g per plant (Figure 2F). *Coffea canephora* plants with one orthotropic branch offer less canopy volume for contact surface and vibration transmission of the rods, justifying the lower harvesting and stripping efficiency compared to coffee plants with two or three orthotropic branches, as found by Mbuge & Langat (2008) and Villibor et al. (2016). Colodetti et al. (2020) observed an increase in canopy area and volume, leaf density, and leaf area of arabica coffee plants with an increase in the number of orthotropic branches. A larger plant canopy volume inside the harvester improves vibration transport throughout the plant, increasing fruit stripping (Souza et al., 2020b). On the other hand, the treatment with three orthotropic branches resulted in a higher fruit loss on the ground due to the difficulty of sealing the lower part of the harvester performed by retractable blades. The three branches created openings that allow the fruit to pass and reach the ground, reducing harvesting efficiency, in agreement with Souza et al. (2020a).

The increase in the vibrating cylinder rotation from 1.0 to 1.5 RPM did not influence the harvesting and stripping efficiencies, fruit loss on the ground, non-harvested fruits, and defoliation, ranging from 46.34 to 47.42%, 58, 49 to 59.87%, 12.15 to 12.46%, 41.51 to 40.13%, and 169.09 to 243.46 g per plant, respectively (Figures 3A, C, and E). Reducing the vibrating cylinder rotation from 1.5 to 1.0 RPM promoted a higher drag of the plant by the rods, but without a greater transmission of vibration (Mbuge & Langat, 2008), not promoting changes in the detachment of coffee fruits and leaves and not influencing the fruit loss on the ground and the percentage of fruits not stripped. Silva et al. (2013) mentioned that harvesting efficiency is increased as there is an increase in the vibration transmission of the rods. Several studies on mechanized harvesting have not evaluated the vibrating cylinder rotation (Silva et al., 2013; Santinato et al., 2015a, 2015b; Souza et al., 2020a), probably because this variable had little influence on stripping and harvesting efficiencies, fruit loss on the ground, non-harvested fruits, and defoliation.

The absence of plagiotropic branches in the lower third of the plants showed a higher harvesting efficiency (80.78%) relative to the presence of branches (75.90%) and no statistical difference was observed for the stripping efficiency, ranging from 91.49 to 92.81% (Figure 3B). Fruit loss on the ground increased from 10.71% in the treatment without branches to 16.91% in the treatment with branches, and the pending load did not differ statistically, ranging from 40.13 to 41.51% (Figure 3D). Defoliation increased from 169.09 g per plant in the treatment without branches to 243.46 g per plant in the treatment with branches (Figure 3F).

The coffee tree grown with plagiotropic branches in the lower third of the plants did not change the stripping process but made it difficult to receive the fruits and clean the impurities, as the leaves and branches break, which reduced the fruit direction to the horizontal transporters. It resulted in a reduction in harvesting efficiency and an increase in fruit losses on the ground, in agreement with Souza et al. (2020a).

The presence of plagiotropic branches in the lower third of the plant increased the leaf area, which contributed to higher defoliation compared to plants without plagiotropic branches. In addition, older leaves predominate in the lower third compared to the upper third of the plant. Older leaves tend to produce more ethylene, causing them to shed more easily due to their natural senescence state, contributing to higher defoliation compared to plants without plagiotropic branches (Alves et al., 2022). Thus, the non-removal of plagiotropic branches from the lower third of the plant would bring economic advantages by reducing the cost of labor to perform the pruning, which would negatively impact harvesting efficiency. According to Baitelle et al. (2019), the removal of plagiotropic branches from the lower third of the coffee tree increases its agronomic and productive performance.

The use of the coffee harvester had an operational cost of US$ 50.31 per hour (Table 1), similar to the value found by Souza et al. (2020b) of US$ 50.13 for the operational cost of harvesting *Coffea canephora*. Cunha et al. (2016) obtained values of US$ 40.90 and US$ 37.59 for two different self-propelled machines for arabica coffee harvesting but which would be approximate if a monetary correction was applied for the inflation of the period. Fixed cost (48.95%) was similar to variable cost (51.05%). The most expensive items in mechanized harvesting were depreciation (28.10%) and maintenance (31.23%).

Manual harvesting reached a cost of US$ 2.15 per harvested bag (80 L), with taxes, which resulted in an average cost per worker of US$ 34.47 per day, added to a quantity of 16 bags in a daily journey of eight hours (average for the region). Thus, the manual harvesting of 1 ha per day, considering productivity of 60 to 140 bags (3,600 to 8,400 kg) per hectare, demands 15 to 35 workers. However, many producers anticipate manual harvesting because of the lack of available workers (Mbuge & Langat, 2008), which results in harvesting with less than 80% of ripe fruits, impairing the quality and final value of the product (Souza et al., 2020b).

The increase in harvesting speed from 800 to 1600 m h^{-1} reduced the total harvesting cost for harvesting efficiency,

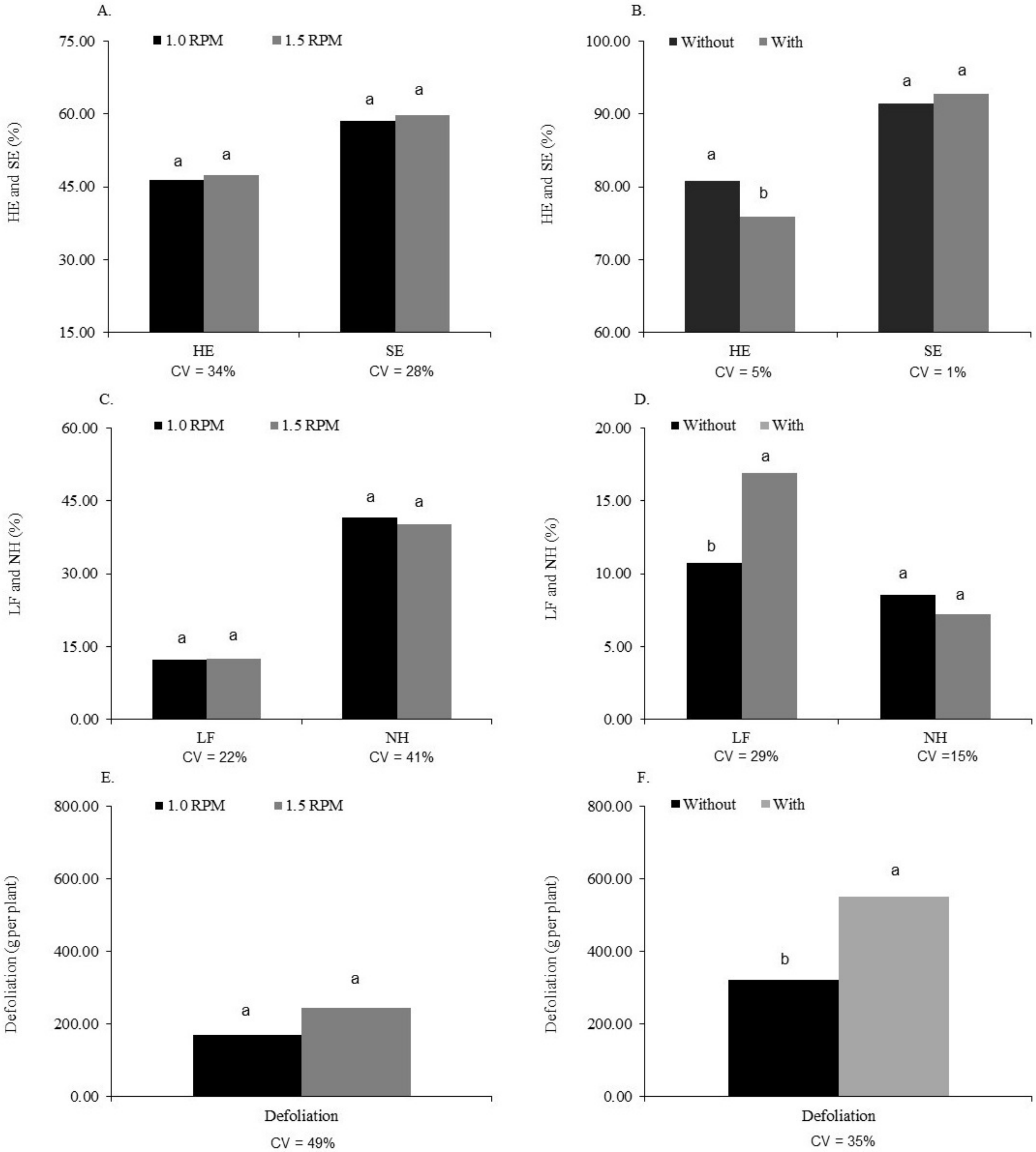


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Figure 3. Harvesting (HE) and stripping (SE) efficiencies, fruit loss on the ground (LF), non-harvested fruits (NH), and defoliation of *Coffea canephora* plants in the vibrating cylinder rotation of 1.0 and 1.5 RPM (A, C, E) and plants with and without plagiotropic branches in the lower third (B, D, F)

fruit loss on the ground, and non-harvested fruits of 80, 10, and 10%, respectively, ranging from US$ 542.71 to US$ 434.91 ha^{-1} in the productivity of 60 bags ha^{-1} and US$ 739.48 to US$ 631.68 ha^{-1} in the productivity of 140 bags ha^{-1} (Figure 4A). These values agree with Kazama et al. (2021), who evaluated the mechanized harvesting of arabica coffee. The unit cost followed the same trend described above, ranging from US$ 9.04 to US$ 7.25 per bag in the productivity of 60 bags ha^{-1} and US$ 5.28 to US$ 4.51 per bag in the productivity of 140 bags ha^{-1} (Figure 4C).

The increase in productivity increased the total cost and reduced the unit cost of mechanized harvesting, ranging from US$ 614.57 to US$ 739.48 ha^{-1} at a harvesting speed of 800 m h^{-1} and US$ 434.91 to US$ 631.68 ha^{-1} at a harvesting speed of 1600 m h^{-1} (Figure 4A). However, the increase in productivity reduced the unit cost, ranging from US$ 9.04 to US$ 5.28 per

Table 1. Cost per hour of mechanized harvesting of conilon coffee using a self-propelled vibrating rod machine

Cost item	Unit	Value	%
Depreciation	US$ h^{-1}	14.14	28.10
Fees	US $ h^{-1}	7.34	14.60
Insurance rate	US $ h^{-1}	1.57	3.12
Occupancy tax	US $ h^{-1}	1.57	3.12
Fixed costs	US$ h^{-1}	24.62	48.95
Fuel	US$ h^{-1}	4.33	8.60
Lubricant	US$ h^{-1}	0.20	0.39
Maintenance	US$ h^{-1}	15.71	31.23
Labor	US$ h^{-1}	5.45	10.83
Variable cost	US$ h^{-1}	25.68	51.05
Total cost	US$ h^{-1}	50.31	100.00

bag (60 kg) at a harvesting speed of 800 m h^{-1} and US$ 7.25 to US$ 4.51 per bag at a harvesting speed of 1600 m h^{-1} (Figure 4C).

Manual harvesting presented higher total and unit costs than mechanized harvesting, with the total cost varying from US$ 708.37 to US$ 1,652.85 ha^{-1} for crops with productivity from 60 to 140 bags ha^{-1} (Figure 4A), while the unit cost remained fixed at US$ 11.81 per bag (Figure 4C). The total cost for manual harvesting increased more significantly with productivity than for mechanized harvesting, ranging from 31 to 123% relative to the speed of 600 m h^{-1}, that is, in the worst-case scenario (Figure 4A). The unit cost of manual harvesting of US$ 14.86 per bag led to an increase in the total cost of this type of harvest as a function of crop productivity, in contrast to the reduction in costs from 23 to 62% with mechanized harvesting, which agreed with Santinato et al. (2015a) and Souza et al. (2020a).

The increase in harvesting efficiency from 60 to 90% resulted in a decrease in the total cost, ranging from US$ 794.74 to US$ 352.01 for crops with a productivity of 60 bags ha^{-1} and US$ 1,385.04 to US$ 352.01 for crops with a productivity of 140 bags ha^{-1} (Figure 4B). The same occurred for the unit cost, reducing from US$ 13.25 to US$ 5.87 for crops with a productivity of 60 bags ha^{-1} and US$ 9.89 to US$ 2.52 for crops with a productivity of 140 bags ha^{-1} (Figure 4D).

The total and unit costs of mechanized harvesting were higher than or equal to manual harvesting with a productivity of 60 and 80 bags ha^{-1} and harvesting efficiency of 60%. However, this result is inverted as productivity increases or harvesting efficiency improves (Figures 4B and D). In other words, the condition presented above is the only scenario

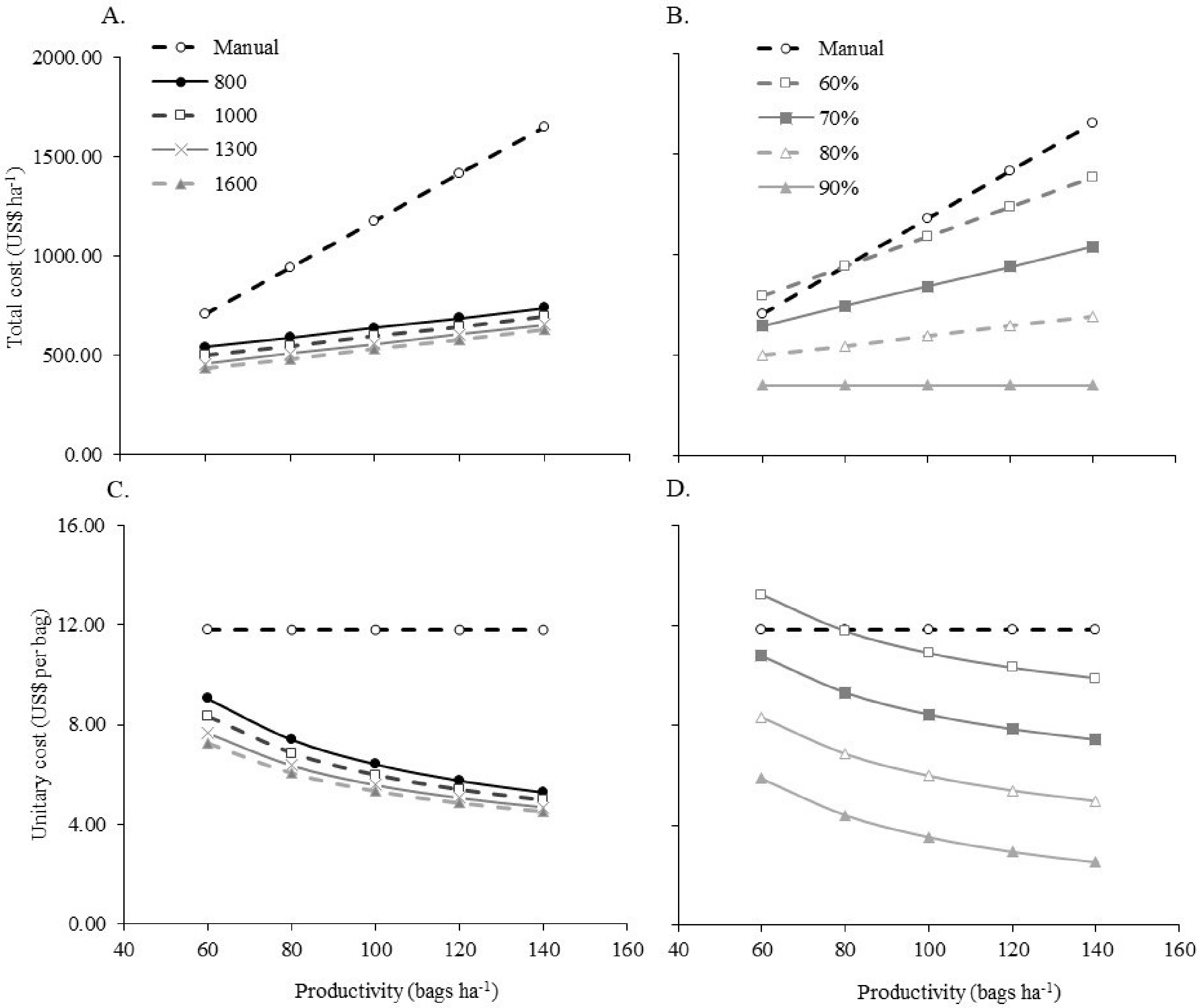

Figure 4. Total and unit cost of manual and mechanized harvesting of *Coffea canephora* as a function of travel speed (A, C) and harvesting efficiencies (B, D) in function of productivity

with a lower cost for manual harvesting than for mechanized harvesting. Harvesting efficiencies above 70% for any yield resulted in harvesting cost reductions from 9 to 79%. According to Souza et al. (2020b), increased harvesting efficiency resulted in lower harvesting costs, regardless of crop productivity.

The total and unit cost of mechanized harvesting is directly proportional to its use, that is, the more used the harvester, the higher the dilution of the financial resource per area or bag (60 kg), in agreement with Lanna & Reis (2012). The search for a lower harvesting cost and, consequently, higher production must be a constant factor in the daily life of the coffee grower, aiming to develop a more economical and competitive coffee production.

Conclusions

1. The increase in harvesting speed reduced stripping and harvesting efficiencies and the speed of 800 m h^{-1} presented maximum stripping and harvesting efficiencies.

2. The coffee tree grown with two orthotropic branches increased stripping and harvesting efficiencies and reduced fruit losses on the ground, the percentage of non-harvested fruits, and defoliation.

3. A coffee tree grown with plagiotropic branches in the lower third of the plants reduced harvesting efficiency due to the higher fruit loss on the ground.

4. Increasing harvest speeds from 800 to 1600 m h^{-1} reduced the total and unit costs by up to 62% compared to manual harvesting. Likewise, increasing harvesting efficiency above 70% reduced the total and unit harvesting cost by up to 79% compared to manual harvesting.

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