ISSN 2359-6562 (ONLINE) 2359-6562 (CD-ROM)

OPERATIONAL COSTS OF GIANT BAMBOO CULTIVATION IN DIFFERENT SOIL PREPARATION SYSTEMS

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ABSTRACT: One of the bottlenecks for expanding commercial bamboo farming in Brazil is agricultural mechanization. The aim of this work was to evaluate the operational performance and to estimate the mechanized cost of soil preparation and planting of giant bamboo in four cultivation systems. The case study of mechanized systems for giant bamboo cultivation was carried out in: area of degraded pasture with conventional soil preparation (PC1); area of eucalyptus regrowth with conventional soil preparation (PC2); area of degraded pasture and no-tillage (PD1) and area of eucalyptus regrowth and no-tillage (PD2). Evaluations of operational field capacity (Cco) were performed to determine the amount of work performed per machine per hour, and total cost (COT) to economically estimate hourly and per hectare costs of operations. The methodology used was proposed by Mialhe (1974) and ASABE (2006). Except for PC2, the planting operation represents a larger share of total costs; direct planting in PD1 and PD2 allows fewer activities in the soil tillage operation and consequent cost reduction. PD1 is recommended.

Keywords*:* *Dendrocalamus asper*, soil preparation, planting, mechanization; agricultural operations.

CUSTOS OPERACIONAIS DO CULTIVO DE BAMBU GIGANTE EM DIFERENTES SISTEMAS DE PREPARO DO SOLO

RESUMO: Um dos gargalos para expandir o cultivo comercial de bambu no Brasil é a mecanização agrícola. O objetivo deste trabalho foi avaliar o desempenho operacional e estimar o custo mecanizado do preparo do solo e plantio de bambu gigante em quatro sistemas de cultivo. Foi realizado o estudo de caso de sistemas mecanizados de cultivo de bambu gigante em: Área de pastagem degrada com preparo convencional do solo (PC1); área de rebrota de eucalipto com preparo convencional do solo (PC2); área de pastagem degradada e plantio direto (PD1) e área de rebrota de eucalipto e plantio direto (PD2). Foram avaliadas: capacidade de campo operacional (Cco) para determinar a quantidade de trabalho realizado por máquina por hora; custo operacional (CO) e custo total (COT) para estimar economicamente os gastos por hora e por hectare nas operações. A metodologia utilizada foi a proposta por Mialhe (1974) and ASABE (2006). Exceto o PC2, a operação de plantio representa maior participação nos custos totais; o plantio direto em PD1 e PD2 possibilita menor número de atividades na operação de preparo do solo e consequente redução dos custos. Recomenda-se o PD1.

Palavras-chave: *Dendrocalamus asper,* preparo do solo, plantio, mecanização, operações agrícolas.

Recebido em 22/04/2019 e aprovado para publicação em 18/05/2020
DOI: http://dx.doi.org/10.17224/EnergAgric.2020v35n2p170-179

1 INTRODUCTION

According to Rambo; Schmidt; Ferreira, (2015); Tiburtino et al. (2015) and Brito et al. (2015), bamboo is an arborescent grass with great potential including biomass for energy production, biodiesel, civil engineering and architecture material, raw material for the pulp, paper, furniture, decorating, pharmaceutical and food industries. In addition, bamboo species can be used in recovery of degraded areas and for carbon sequestration (RIBEIRO et al., 2016).

According to Oprins; Trier; Maertens, (2006), carbon sequestration has been considered of great relevance to contain the negative effects of greenhouse gases on the climate, especially carbon dioxide (CO_2). The authors cite that, bamboo has the capacity to recycle 12 tons per hectare of CO_2 from the atmosphere. Also reported that the amount of carbon stored in the bamboo forest is 40-45% of the total biomass.

According to Guarnetti and Coelho (2014), and Drumond and Wiedman (2017), one of the bottlenecks for large-scale bamboo crop productivity is agricultural mechanization in cultivation. Howwever, the authors mention that the labor costs employed in the bamboo growing phase represent an average of 34% of the production cost in Brazil, an excessively high percentage when compared to other silvicultural crops such as pine. For this crop the labor cost in the field cultivation phase is 5.2%, due to the use of machines in crop operations (MIRANDA, 2016).

To increase the productive scale of the crop there is a need for more scientific, technological, mechanized operation and use of inputs (OSSE; MEIRELLES, 2011). For this reason, Scorupski et al. (2017) indicated that selection of the production system and adequacy of the agricultural machinery, knowing their operational performance and costs, constitute a challenge for the productive development of any forest crop in Brazil, where machinery for many operations is very specific and has high costs.

According to Baio et al. (2013), mechanization is an agricultural practice that assists in meeting the productive and market requirements of agribusiness. According to Piacentini et al. (2012), the use of machines seeks to improve production systems, resulting in agility and quality of operations at a minimum financial cost. The more complex the mechanized system, the greater the qualitative and economic requirements of the operation, in the sense of minimizing costs and maximizing operational performance (ARTUZO et al., 2015).

The operational performance of agricultural machinery is a complex set of information that determines, depending on its characteristics, the productivity when performing operations under certain working conditions, provided in units of hectares worked per unit time (MIALHE, 1974). Similarly, Pequeno et al. (2012) cited that the operational cost is due to the characteristics of the work and operational performance under certain working conditions, where the cost is given in monetary unit per unit time and/or area.

In the Federal District and its surroundings, rural producers have used bamboo cultivation as an alternative for income diversification and land use, especially in areas with degraded pasture or freshly harvested eucalyptus, where low remuneration of production has discouraged activities. The objectives of this work were to evaluate the operational performance and to estimate the cost of mechanized agricultural operations for soil preparation and planting in four giant bamboo cultivation systems.

2 MATERIAL AND METHODS

A case study of mechanized systems for cultivation of giant bamboo (*Dendrocalamus asper*) was carried out at the Água Limpa Experimental Farm, located in Brasília - DF and linked to the University of Brasília. Primary data was obtained from the assessment of machines, equipment, operations and activities required to prepare the soil and for planting of giant bamboo seedlings, performed in November 2016.

Operational performance and cost of mechanized operations to prepare the soil and plant giant bamboo were performed in the following cultivation systems: degraded pasture area with conventional soil preparation (PC1); area of eucalyptus regrowth with conventional soil preparation (PC2); area of degraded pasture and no-tillage (PD1) and area of eucalyptus regrowth and no-tillage (PD2). Conventional soil preparation in PC1 and PC2 comprised the clearing and intense mobilization of the soil with harrowing operations.

Planting was carried out with a space arrangement of six meters between seedlings and nine meters between rows, adapted from Pereira and Beraldo (2008) to technically allow for traffic of machines among the seedlings, and for planting in an area with eucalyptus regrowth. The activities performed in soil preparation and planting operations are identified in Table 1, and the treatments that used them, the application frequency and the year of application were informed.

Table 1. Operations, application frequency and year of application of the operations used in preparation of the soils and planting of giant bamboo.

Operation	Activities	Treatment				Cultivation year
		PC1	PC2	PD1	PD2	
Soil preparation	Stump removal/windrowing		1			1°
	Clearing the area		1			1°
	Lime distribution	2	2	2	2	1°
	Intermediate harrowing	2	1			1°
	Leveling harrowing	1	1			1°
	Desiccation			1	1	1°
	Trimming				1	1°
Planting	Furrowing	1	1	1	1	1°
	Distribution of seedlings	1	1	1	1	1°
	Basic fertilization	1	1	1	1	1°
	Planting	1	1	1	1	1°
	Crowning	2	2	2	2	1° and 2°

*Number of times performed during the first five years of giant bamboo cultivation.

The stump removal operation in treatment PC2, comprised of removing the remaining eucalyptus stumps after harvest and their disposal, was performed by renting a Caterpillar-D6 model bulldozer, with 111.8 kW (152 HP) of power, front blade measuring 3.86 m x 1.15 m and cost of R$ 150.00 h^{-1}. In treatment PD2 stump removal was not performed. Instead the trees were cut with tractor-mounted hydraulic saws and 15 days later the stumps were killed with herbicide. Bamboo seedlings were planted among the eucalyptus stumps, aiming to reduce the traffic of machines in the area and the intense mobilization of soil resulting from stump removal.

The activities of soil clearing, seedling distribution in the planting furrows, lime and gypsum application in total area, basic and cover fertilization, spraying, mowing and irrigation were performed with a tractor model NH TL75E 4 x 2 TDA, with 57.3 kW (78 hp) of gross engine power. The agricultural trailer used for the transport of seedlings and fertilizer was model CBC4.5 with load capacity of 4,500 kg. For the distribution of lime and gypsum, a Netz CT260 loader with a capacity of 0.26 m3 was used, and a volumetric distributor of model IPacol DSE5500 with load capacity of 2.75 m3 and application range of 8 m.

The application of pesticides was carried out using a PJ401Jacto model bar sprayer, with 600 L capacity in the tank, 12 m spray boom, 12 nozzles spaced at 0.5 m, two directed spraying booms and 11002 nozzle tips. Mowing was conducted with a model RDU1500 tractor, consisting of two horizontal blades driven by the tractor power take-off and cutting width of 1.5 m.

Localized irrigation of bamboo plants was carried out with a tank truck, model Mepel CARTBB, with a 4.000 liter capacity, hydraulic pump driven by the power take-off and two lateral hoses measuring six meters long equipped with adjustable nozzles of 1½".

For intermediary harrowing, leveling, trimming and furrowing activities a tractor was used, model TM7020 4 x 2 TDA, with 109.5 kW (149 hp) of gross engine power. The equipment for intermediate and leveling harrowing operations used were: model Baldan CRI 18 x 28" x 6 mm, cut discs spaced at 270 mm, working width of 2.3 m and weight of approximately 2,061 kg; and model Tatu Marchesan GN32 32 x 22" x 3.5 mm, disks spaced at 195 mm, working width of 2.9 m and weight of approximately 860 kg. Furrowing for planting of the seedlings was carried out with a Baldan PSH hydraulic soil drill, equipped with a drill measuring 18" in diameter x 1000 mm in length.

The activities of land clearing, seedling distribution, base fertilization in the planting furrows, seedling planting, crowning of seedlings, coverage fertilization, ant control and irrigation utilized daily manual labor of workers. Except for the planting of seedlings, which required six workers, and ant control and irrigation, which required two workers, the other activities employed four workers. The average remuneration per rural worker was obtained in the Rural Union of the Federal District, being considered of R$ 80.00 per day of eight hours of work.

The hourly (CH) and operational costs (CO) were calculated separately for the soil preparation and planting operations. The methodology used to analyze the costs was proposed by the American Society of Agricultural and Biological Engineers (2006), where the CH is divided into fixed costs and variable costs. The fixed cost is obtained by the sum of the costs of depreciation, interest, accommodation, insurance, fees and salary of the machine operator. The variable cost is obtained by summing up the costs of fuel, grease, lubricating oils, repairs, maintenance and labor of day workers.

Calculations of the CH and CO were performed using Equations 1 to 8.

$$CO = \frac{CH}{Cco} \quad (1)$$

$$CH = CFH + CC + CRM + CMO \quad (2)$$

$$CFH = \frac{CFA}{NHTa} \quad (3)$$

$$CFA = Vi[Dpa + (Ja \times i) + FAST + Vi] \quad (4)$$

$$NHTa = \frac{Vuh}{Vua} \quad (5)$$

$$CC = Ch \times Pc \quad (6)$$

$$CRM = FRM \times \frac{Vi}{Vuh} \quad (7)$$

$$CMO = \frac{S+E}{NHTm} \quad (8)$$

Where: CO is the total operating cost given in R$ ha^{-1}, CH is the hourly cost of machinery given in R$ h^{-1}, Cce is the effective field capacity given ha h^{-1}, CFH is the fixed hourly cost in R$ h^{-1}, CC is the fuel cost in R$ h^{-1}, CRM is the cost of repairs and maintenance in R$ h^{-1}, CMO is the labor cost of the operator in R$ h^{-1}, CFA is the annual fixed cost in R$.$year^{-1}$, NHTa is the number of hours worked per year, Vi is the initial value for acquisition in R$, Dpa is the annual depreciation in R$, Ja is the annual interest rate, i is the interest rate as a percentage (%), FAST is the factor of lodging, insurance and fees in percentage (%), Vuh is the useful life of the machine in hours, Vua is the useful life of the machine in years, Ch is the hourly fuel consumption in L.h^{-1}, Pc is the fuel price of R$ 3.54 L^{-1}, FRM is the percent factor of repairs and maintenance of the machinery, S is the monthly salary in R$, E is the monthly value of worker benefits and NHTm is the number of hours worked per month.

The hourly fuel consumption (Ch) was determined by the ratio between the quantity of diesel fuel consumed and the number of hours worked per activity performed, where the result was given in $L.h^{-1}$. The operational performance given by the operational field capacity (Cco) was determined by the ratio of area worked and time demanded, with the result given in ha h^{-1}.

The Vuh and Vua were obtained according to American Society of Agricultural and Biological Engineers (2006) and the Vi of each machine was determined by acquiring quotations in the region of Brasília-DF. The value of Ja was set at 7.5% per year, according to the Government Fleet Modernization Program - Moderfrota 2020 (BANCO NACIONAL DO DESENVOLVIMENTO, 2020). The FAST was defined as 0.5% per year, according to Mialhe (1974). The monthly salary of the operator was defined as R$ 1,450.00, with a 96.27% increase for benefits (13th salary, vacations and INSS), and a working period of 176 hours per month (22 days a month and a working day of 8 hours).

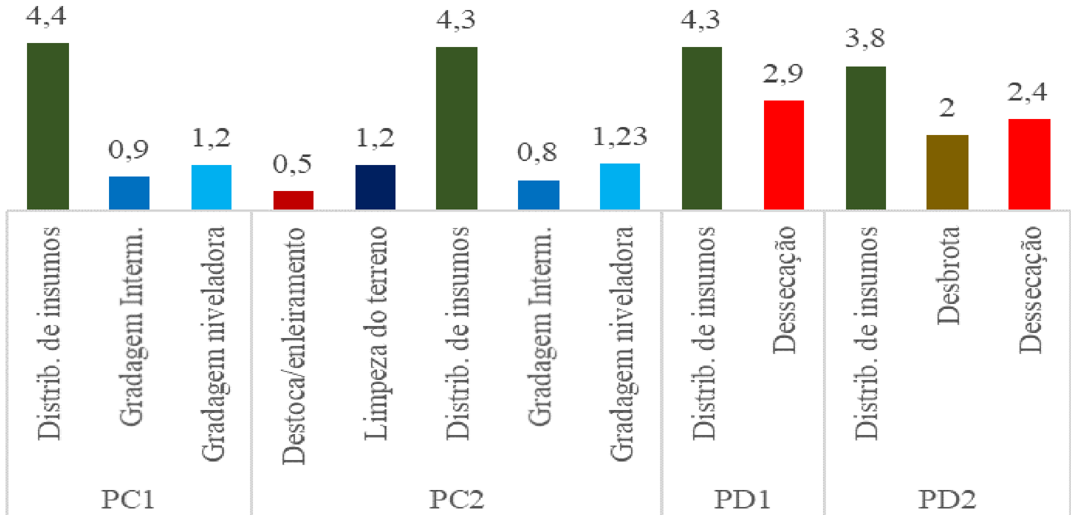
The total operational cost (COT) was determined from the sum of CO values for the soil preparation and planting operations, given in R$ ha^{-1}.

The data obtained was analyzed via descriptive statistics, considering that it is real operational and economic performance data, with no potential for differences among repetitions.

3 RESULTS AND DISCUSSION

The results of operational field capacity (Cco) for the soil preparation activities are shown in Figure 1.

Figure 1. Operational field capacity (ha h^{-1}) of the soil preparation activities.



Treatment PC2 presented the greatest number of soil preparation activities, five in total. The presence of eucalyptus stumps required their removal and clearing the land in PC2, requiring 40% more activities than PC1 and PD2, and 60% more than PD1. Although PC1, like PC2, was cultivated in conventional soil preparation, in the degraded pasture area no soil clearing was necessary and soil preparation required only intermediate and leveling harrowing.

Among all the operations performed, the distribution of inputs presented the highest Cco in all treatments, average of 4.2 ha h^{-1}. This result was obtained due to this operation being carried out with equipment that applies solid input to the haul, consequently the application range (working width) becomes larger than that of the other operations, giving a larger Cco, that is, operation that covers a larger area worked (applied) per hour. However, among the cultivation systems, Cco differed. In PD2 to Cco the input distribution was 7.1% lower than the average of the treatments, as in the desiccation it was 17.2% lower than the Cco obtained in PD1. The results of Cco in PD2 can be justified because the working speeds in the distribution and the pulverization of inputs are reduced by the presence of stumps and traces of forest harvesting in the area. . In the working condition of this area, greater vibrations, bumps and balancing of the tractor and sprayer were observed, reducing the ergonomics, comfort and safety of the operator and the mechanical integrity of the machinery, correctly inducing the operator to reduce the working speed and consequently the Cco of the operations.

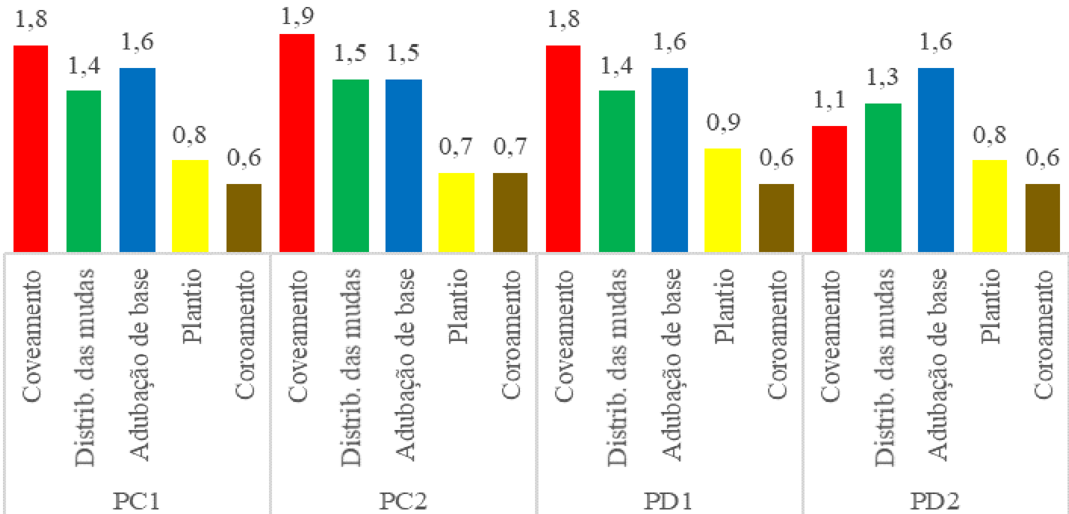
The lowest Cco, 0.55 ha h^{-1}, was observed in the stump removal operation, obtained due to the understandable degree of difficulty of the bulldozer for the removal of stumps from the soil, filling of the holes with soil and clearing of the stumps; these maneuvers therefore required excessive time and consequently presented low operational efficiency. The result is 20% lower than that obtained by Casselli (2013) who evaluated the eucalyptus cutting operation with a hydraulic excavator and tubular saw.

Comparing PC1 and PC2 (conventional tillage) with PD1 and PD2 (no-tillage), in conventional systems the activities presented lower Cco. This result can be justified due to the technical characteristics of each preparation system and the machinery required. According to Sales et al. (2016), in conventional preparation intense soil mobilization occurs with plows and harrowing in the pre-planting phase, aiming mainly to improve soil physical characteristics and for weed control. This definition and that described by Silva et al. (2015), which is characteristic of the harrowing operations and presents reduced Cco in relation to sprayings, justifies the Cco results obtained in PC1 and PC2.

PD1 and PD2 present higher Cco values, since according to Andrade et al. (2017) in the no-tillage system there is no soil mobilization in preparation for planting. Soil preparation is carried out with sprayers for the application of desiccant herbicides or simply management of weeds with tillers or mowers, activities with high Cco. Thus, the results of this work corroborate with the characteristics of each type of soil preparation.

The results of operational field capacity (Cco) for the operations performed at planting are presented in Figure 2.

Figure 2. Operational field capacity (ha h^{-1}) of the planting operations.

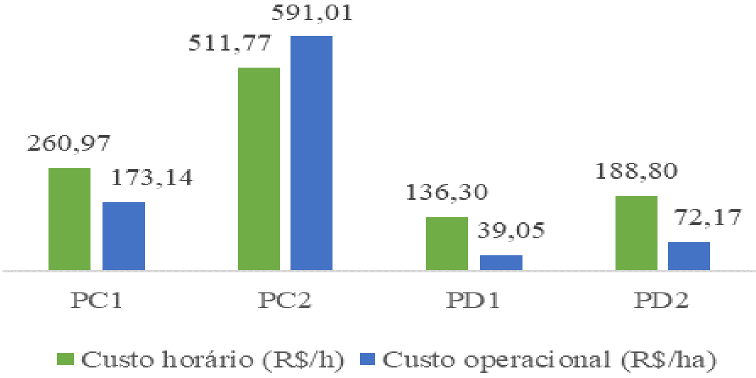


Among the operations performed in the planting phase, which presented the greatest discrepancy between treatments was furrowing in PD2. The Cco of this operation in PD2 was 1.1 ha h-1, which is 33.3% lower than the average of 1.65 ha h-1 among all treatments. The reason for this difference, as in the distribution of inputs and desiccation for soil preparation, is the condition of the soil in PD2. The presence of eucalyptus stumps in the bamboo planting lines, spaced two meters apart, became an obstacle for mechanized soil furrowing. The large quantity of roots from the stumps reduces the rotational speed of the drill bit, also reducing the drilling capacity and penetration into the soil. In addition, greater drill bit wear was observed, with early cracks, breaks and cutting losses.

The other operations presented similar Cco values among the treatments.

The results of hourly cost (CH) and total operational cost (CO) of the soil preparation operations are presented in Figure 3.

Figure 3. Hourly costs (CH) and operational costs (CO) of the soil preparation operations.



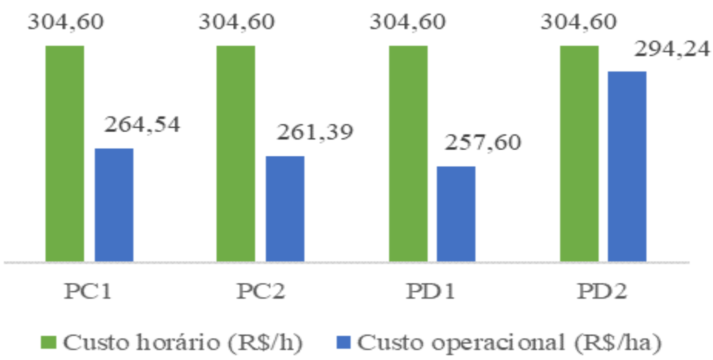
The lowest CH and CO values were obtained in PD1, R$ 136.30 h-1 and R$ 39.05 ha-1, respectively. The CH of this treatment was 47.7, 73.3 and 27.8% lower than the CH of PC1, PC2 and PD2, respectively. In relation to CO, in PD1 it was 77.4% lower than in PC1, 93.4% lower than in PC2 and 45.9% lower than in PD2.

Comparing the results of CO with those of Cco from Figure 1, it is possible to understand that the lower CO of PD1 was possibly due to the use of three operations for soil preparation, distribution of inputs, stump removal and desiccation, each with high Cco. According to Mialhe (1974), the higher the Cco the lower the CO of the agricultural operation, justifying the results found.

Contrary to the CO result of PD1, PC2 had a higher CO value due to the greater number of operations to prepare the soil and these presented lower Cco, as observed in cutting and harrowing.

The results of hourly cost (CH) and operational cost (CO) of the planting operations are presented in Figure 4.

Figure 4. Hourly cost (CH) and operational cost (CO) of the planting operations.

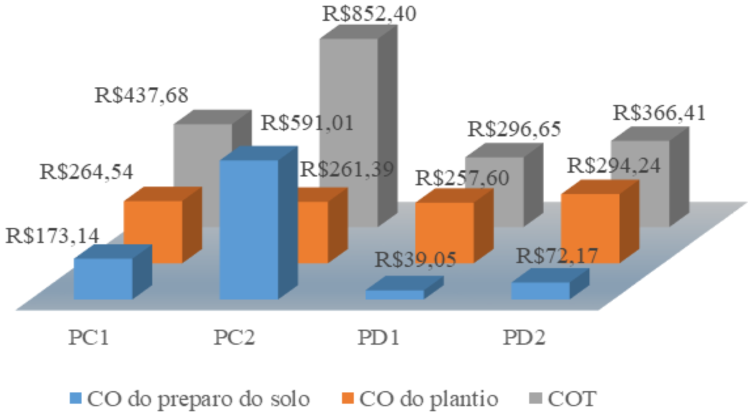


In the planting operation, the CH did not differ among treatments, being R$ 304.60 h-1. This was because the operations and machines used were the same in the treatments, so the CH was the same.

Because the Cco of the planting operations in PC1, PC2 and PD1 presented approximate values, the CO among them was also equivalent. However, due to the economic performance studies of agricultural operations performed by Jasper; Silva, (2013) and Cunha et al. (2016), when considering all differences, although minimal between the absolute values, the CO of PD1, R$ 257.60 ha-1, was 2.6 and 1.4% lower than PC1 and PC2, respectively. The highest CO of the plantation was obtained in PD2, costing R$ 294.24 ha-1, a value 12.4% higher than PD1. This difference occurred due to the lower Cco of the furrowing operation in PD2, requiring 63.6% more time to open the furrows between eucalyptus stumps.

The results of total operational cost (COT), obtained by the sum of CO values for soil preparation and planting, are presented in Figure 5.

Figure 5. Total operational cost (COT) in R$ ha^{-1}.



The highest COT was recorded in PC2, R$ 852.40 ha^{-1}, obtained due to the land clearing operation which represents 69% of the COT in the treatment. The lowest COT, R$ 296.65 ha-1, was verified in PD1, where the soil preparation operations are fewer in number and have a high Cco, representing 13% of the COT.

In general, no-tillage treatments (PD1 and PD2) showed the lowest COT. With the exception of PC2, the operational costs of planting presented the greatest percentage of the COT. The major cost in PC2 was related to soil preparation resulting from stump removal in conventional tillage.

4 CONCLUSIONS

Among the giant bamboo farming systems studied, it is concluded that: except for PC2, the planting operation represents a greater participation in the total costs, and studies must be carried out to improve and innovate the mechanization of the operation, still performed manually; no-tillage in both degraded pastureland and eucalyptus regrowth area, PD1 and PD2, respectively, allows a smaller number of activities in the soil preparation operation and consequent reduction of costs. It is recommended based on the smaller number of operations for soil preparation, better operational efficiency and lower estimated total cost with tillage and planting, the giant bamboo cultivation system in PD1.

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